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World's Largest Telescope Sees First Light

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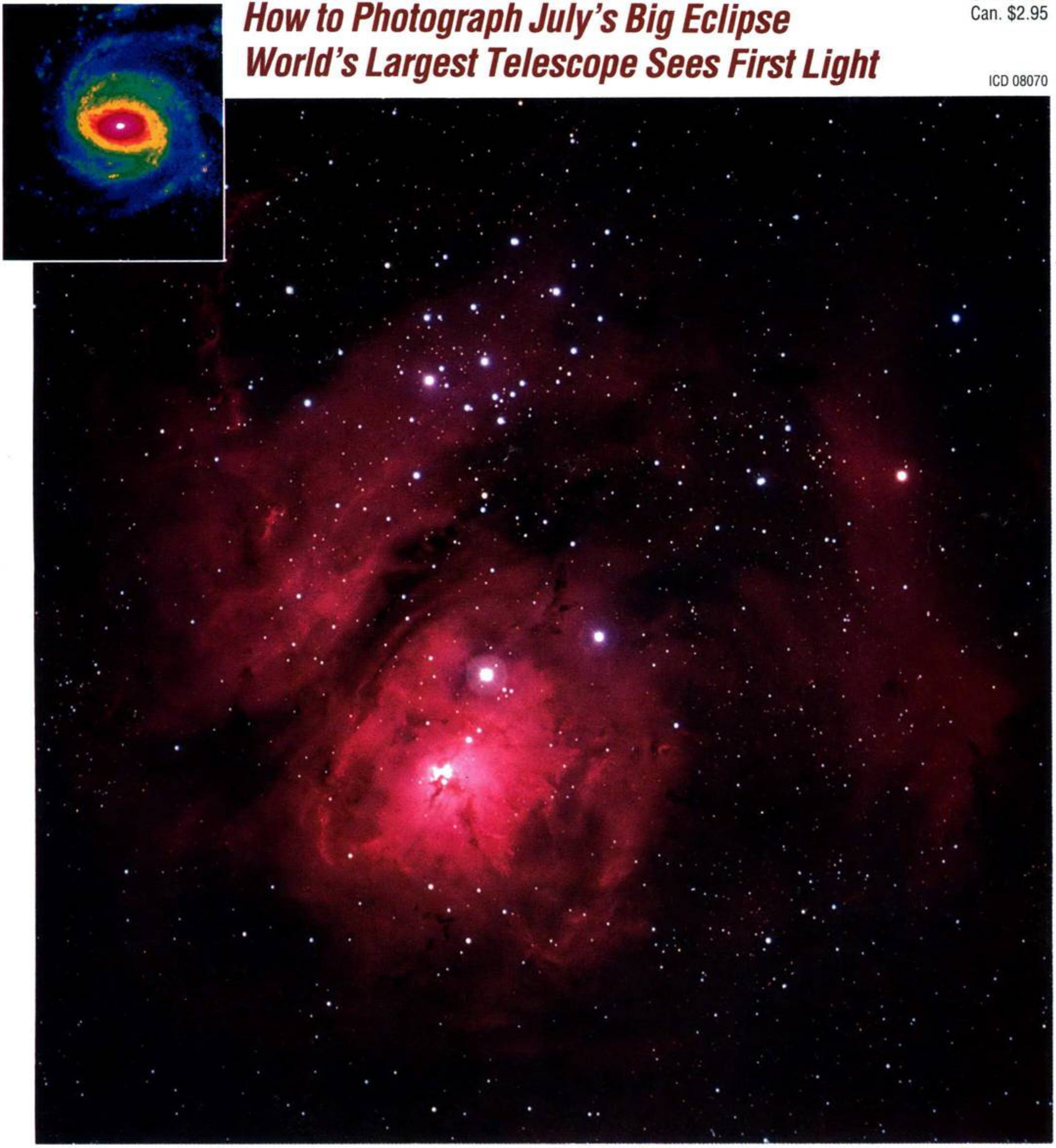

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The Meade Accessory Package, shown with standard-equipment SP 26mm eyepiece.

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This offer is valid only in the USA and Canada and applies only to telescopes purchased ***between February 1, 1991, and April 30, 1991.*** *Registration Cards and invoice copies sent to Meade Instruments must be postmarked not later than May 15, 1991.*

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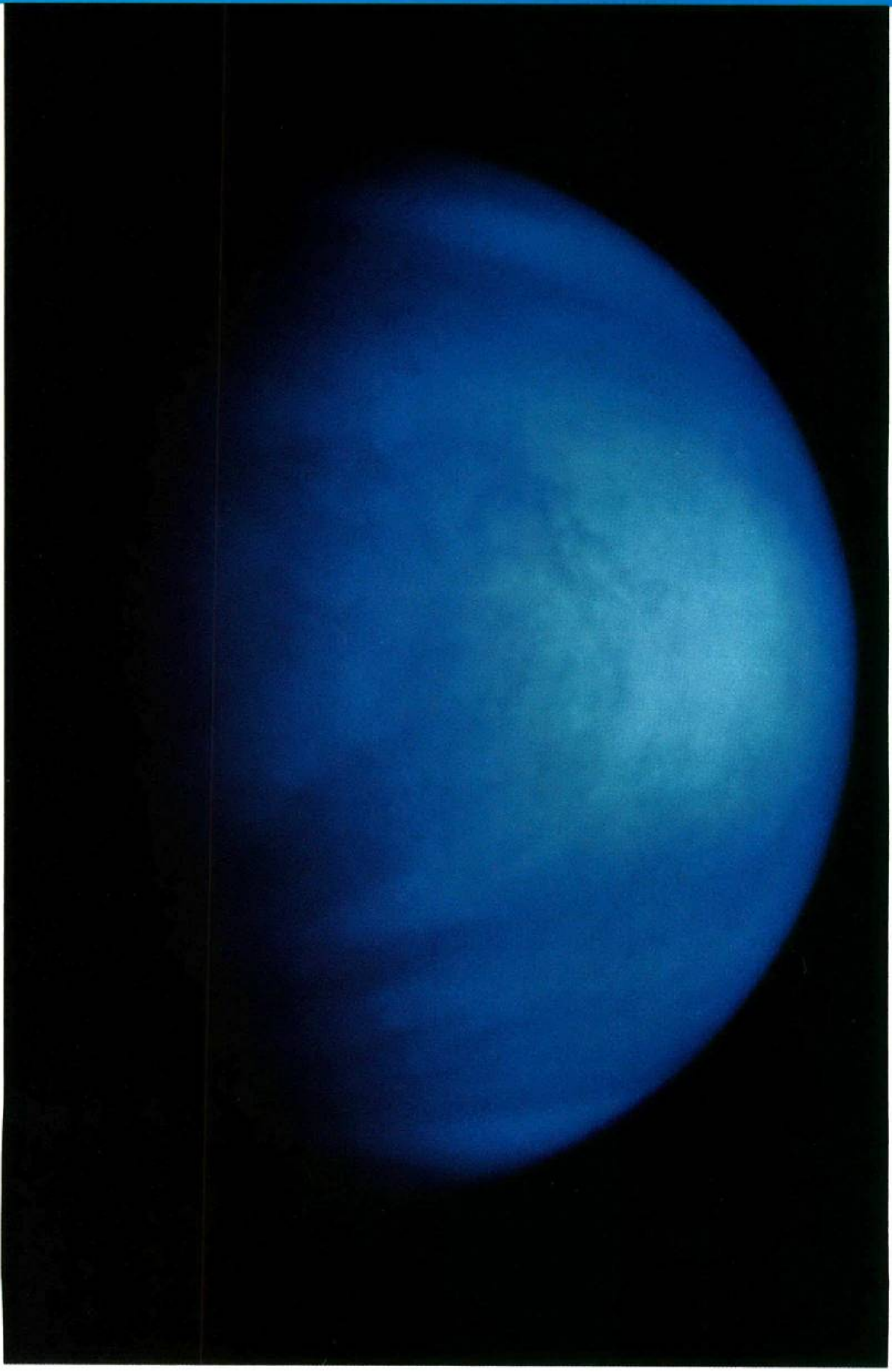
ON THE COVER: The ghostly swirls of the Lagoon Nebula in Sagittarius have delighted generations of summertime sky watchers. But why wait until then? You can see this celebrated object already this month, in the quiet hours between midnight and dawn. Kitt Peak National Observatory photo.



A NEW VIEW OF VENUS was revealed by the *Galileo* space probe. This violet-light image shows Venus much as your eye might see it close up. For more Venus images from *Galileo*, see page 38. NASA/JPL photo.

ASTRONOMY®

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The
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Behind the Scenes

DON'T FORGET YOUR FILM!

There are two schools of thought on eclipse photography. One school says that if you travel to an eclipse, you owe it to yourself to observe and experience the event as fully as possible. If you have to fiddle with film and f/stops, they claim, a vital part of the eclipse experience will pass you by.

Their opponents claim that taking pictures preserves the eclipse experience better than memory does. If you take pictures, you can savor the sight again and again. You owe it to yourself, they say, to take pictures and prove your technical mettle.

The discussion soon becomes heated. As the conflict escalates, the technophiles brand their non-picture-taking friends "technophobes." They haul out slides from the last eclipse and challenge their filmless counterparts to recall from memory the delicate streamers the slides show so well.

The eclipse viewers retreat to rhapsodies about the colors and the smells and crowing roosters that never make it onto film. Then they counterattack, questioning whether the "camera operators" even saw the eclipse outside the narrow confines of a camera viewfinder. "Hah!" they retort, you may have some pictures but there were far better pictures in ASTRONOMY magazine.

And that's how we get involved. Within days of a solar eclipse, airbill packages and boxes wrapped in thick layers of Fiberglas tape roll into our offices. We free the precious Kleenex-wrapped prints from their airtight and watertight prisons of tape and foam and read the letters that accompany them. "Dear Sirs: Picture #1 is f/8 at 1/125th, Picture #2 is f/11 at 1/15. Both are Kodachrome. Thank you, Sal Jones." Hmmm! Are we to believe the technophobes?

On the other side of the ASTRONOMY mail room a few bushel baskets full of letters have arrived. Thick letters. Letters overflowing heartfelt experience, telling of wonder and beauty and magnificence. We're awed at the display of descriptive talent. And what did it look like? Oh, it was wonderful to see. Do the technophiles have a point?

Well, we don't think there's really a conflict. Both camps clearly loved the eclipse, and both got something meaningful from it. Besides, if you stick to simple camera equipment that you're familiar with, you can observe everything around you and shoot a roll of film, too. The best of both worlds.

We're planning to publish the biggest and best eclipse report ever assembled. So write those thoughts in thick letters — and mail them to ASTRONOMY. Bundle your pictures into secure packages — and mail them to ASTRONOMY. We'd like your thoughts and your pictures for the pages of ASTRONOMY — your magazine.

Sincerely

Richard Berry

Richard Berry
Editor-in-Chief

ASTRONOMY

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Letters

How to Combat Light Pollution...with Tact!

I read a letter to the editor in your January issue that astonished me. The author recommended shutting off offending streetlights and offered a "clever" way to do this by shining a bright light into the light's photocell. All observers are concerned about light pollution, and many of us have taken the initiative to do something about it. But disabling streetlights is, if not illegal, certainly mischievous. Please don't give those of us trying to interact intelligently with our communities a bad name. — *Leo White, Delaware Valley Amateur Astronomers, Philadelphia, Pennsylvania*

Is There Hope for Teenage Astronomers?

I enjoyed reading Thomas Pannuti's "Ballad of a Teenage Astronomer" (Viewpoints, December). Let it be known that I am also a teenage astronomer. Astronomy became a passion for me during high school, even though I had been interested in science and outer space for most of my childhood. It strikes me as weird that many times I've been called an "oddball" or an "egghead" because I told someone I was really interested in astronomy in particular and science in general. While other kids my age dream of being doctors, lawyers, and millionaires, I fantasize about being an astronomer and discovering the secrets of the universe.

Over the past couple of years, however, I think I've detected something of a change. People seem to be more accepting of science and technology today and are becoming more aware of the environment, on Earth and in our celestial surroundings. Still, science in school has a reputation for being dull, complicated, and suitable only for those with an IQ of a zillion. It's sad to think that many high school and junior high students dread taking any physical or life science, and many only do it because it's a requirement for graduation.

Even worse, there's an active contempt for science by many kids — despite the fact that they listen to Walkmans and cook lunches in microwave ovens. I remember that when I was horrified at the 1986 *Challenger* explosion, lots of kids at school couldn't understand why. Some even had comments about the explosion ranging from "Wow!" to "How cool!"

Things are slowly improving for teenagers and their interest toward science, as Pannuti's article pointed out. How-

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	LX5	**1,2,3,4,5,6,9**
	LX6	**1,2,3,4,5,6,9**
	DS10	**1,2,3,4,5,7**
	DS16	**1,2,3,4,5,7**
	2040	**1,2,3,4,7**
	2045	**1,2,3,4,6,7**
	2045D	**1,2,3,4,6**
	2080/2120 GEM	**1,2,3,4,5,6,8**
	6600/8800	**5,6,8**
	295/310/320	**5,6,8**
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	880/1060/1266	**1,2,3,4,5,7**
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	6600/8800 MTS	**1,2,3,4,6**
CELESTRON	***CELESTRON***	
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	C-14	**1,2,3,4,5,6,9**
	Ultima 8*	**1,2,3,4**
	Ultima 11*	**1,2,3,4**
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	SPC-90/SPC-102	**1,2,3,4,5,6**
	Polaris C60/C70/C80/C100	**5,6**
	Polaris C-6/C-125	**6**
	Polaris C-4.5	**5,6**
	C-5	**5,7**
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ever, we still have a long way to go. Sure, I love to do all the normal things teenagers like to do, but give me a pair of binoculars under a clear, dark sky and I'll be entranced for hours. Come out of the closet, teenage astronomers! Don't allow the limited visions of other kids ruin what will be the greatest adventure of your life! — *Thomas May, Moreno Valley, California*

Back to the Basics

Your article "Where is Astronomy Going?" (Viewpoints, September 1990) was thought-provoking and needed to be done. After considering my own situation and those of many in astronomy clubs, I think several fundamental points should be made. First, there are so many facets of astronomy that even if I live to be 100, I couldn't possibly enjoy them all. Second, the serenity of gazing at the stars would be spoiled if I had to set up lots of complex equipment each observing session. Third, young people are scared off by the apparent high cost and superabundance of complex equipment that dominates the hobby these days.

From these points, I think the key to astronomy should be simplicity. It's not a contest to see whose equipment is the most expensive, but rather a mutual enjoyment of the heavens. Get back to the basics — the Moon and the Orion Nebula, and tell people what they can see with binoculars and small scopes. You'll then be doing the greatest service to the hobby you possibly can. — *William R. Salle, Seattle, Washington*

Have You Been Harassed?

I am conducting a study of discrimination, harassment, and sexism in astronomy. Whether you are male, female, amateur, or professional, I would be most interested in hearing your comments on this subject. — *Jill S. Price Mason, Natural Sciences Department, Bentley College, 175 Forest Street, Waltham, Massachusetts 02154*

Pondering Hubble

Extreme dismay and disbelief was my reaction when I opened my November issue and read "The Trouble with *Hubble*" (Letters). Given the media's early coverage of *Hubble's* problems, however, I shouldn't have been surprised. With respect to old-fashioned accountability, NASA did not technically build the craft and therefore cannot be fully at fault. Under standard operating guidelines, the work was contracted out to industry. Why don't we hear about an investigation of the contractors, rather than NASA? It's too bad the space agency can't return the craft to the "dealer" for a repair job!

I think it's important to eliminate the double standard we apply to the space program relative to other human endeavors. It seems the public expects that the space program should be easy, without any failure, and that any failure constitutes grounds for abolition. If this attitude held true for other activities in our society, we could hardly do anything new at all!

Space is our generation's frontier. To date, our exploration of space constitutes a grand achievement that everyone can be proud of. What a shame it would be to turn away from space exploration and our exploration of the universe because the going wasn't easy at first. — *Jim Plaxco, Schaumberg, Illinois*

What gives with the *Hubble Space Telescope*? On page 22 of the November issue we are informed that *HST* images "far surpass those taken with ground-based telescopes." Yet on page 33 of the same issue a diagram reveals that "*HST's* star images are little better than ground-based star images." Someone must have been asleep at the eyepiece, and I, for one, am as confused as the *Hubble* engineers. — *Anthony Moore, Tampa, Florida*

— In our November stories two different standards for image quality were employed, one strict and the other general, in order to demonstrate the extent of the flaw with Hubble's primary.

I was very sorry to hear about *Hubble's* problems with spherical aberration. However, it strikes me that things might not be as bad as they seem. In x-ray analysis of crystal structures, the diffraction pattern produced by a crystal is routinely used to reconstruct the actual position of the atoms in the crystal by the mathematical process called Fourier transformation.

If *Hubble's* actual mirror form is known from the computer program that controlled the grinding machine, then scientists ought to be able to apply some sort of correction to all of the images to concentrate the light from stars and other objects in this same way. This could help *Hubble* see much fainter stars than it might with its aberration, and extended objects would be greatly helped. — *Jack Coleman, Ruislip, Great Britain*

The report "*Hubble's* Optical Fix"

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(November issue) was a fine, balanced assessment of the state of *Hubble* science, an excellent rebuttal to some of the hysterical exaggerations I've heard recently. The sidebar explaining spherical aberration was both informative and thought-provoking. The central black holes visible in the first and last panels and labelled "out of focus" probably represent a special circumstance, the shadow image of the secondary mirror.

ASTRONOMY readers with telescopes that suffer from spherical aberration might be able to stop-down their telescopes to reduce the effect as much as they can. Certainly we can learn something positive from all of this and look forward to a brighter future for NASA and the American space program. — *David L. Weisman, Culver City, California*

— *NASA has already begun to use several of the techniques mentioned by well-intentioned readers in their letters about* Hubble. *We feel that the outlook for both* Hubble *and the future of NASA's planetary exploration program is not nearly as bleak as it appears to many readers, and that* Hubble *will prove to be the most valuable tool in the history of astronomy within the coming years.*

ASTRONOMY without Moon?

It appears as though the proofreaders at ASTRONOMY may have taken "The Earth Without the Moon" (February 1991 issue) a tad bit too serious. You will note that the solar system chart for February lacks Moon phases; only blank white circles appear where the Moon phases should. This lunar lunacy perhaps best sums up how ASTRONOMY would be if Earth had never been granted the luxury of a Moon. At least be thankful that the article wasn't "What if low-cost Schmidt-Cassegrain telescopes had never been developed?" — *Brad White, Grover, Missouri*

Correction

The bright and dark portions of the lunar disk were inadvertently reversed in the diagrams on page 61 of the February 1991 Sky Almanac. ☐

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

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MAKING THE SKY ACCESSIBLE

By Jim Moeller

At a star party I attended recently, several people were discussing how to bring the hobby of astronomy to people with disabilities. Because I use a set of aluminum crutches, I was naturally drawn to the discussion. The group wanted to know how astronomy was different for me than for able-bodied people. This set me thinking about how my hobby has changed for me since my auto accident some 11 years ago.

First and foremost, the idea of having an accessible site has become the most important factor for me. I've found that a site without large ruts, rocks, or steep grades is best. The smoother the surface, the better.

The second priority for me has become the need for a very portable telescope. My definition of portability is probably different from most. I need a telescope that I can pick up and carry while I'm using my two "aluminum friends." At first, this made for some rather humorous attempts at observing. At the time, however, the humor escaped me, but in looking back . . . ah well, we all learn by doing! My current telescope is a homemade 3.25-inch refractor with a 700mm focal length. The total weight, including the tripod, is only 4 pounds. It does not have an equatorial mount, but that actually makes my observing easier as the eyepiece is always in a convenient viewing position. The reduced weight allows me to transport my scope by attaching a camera strap and slinging it over my shoulder.

I've also learned the joys of binocular viewing. Courtesy of an article which ASTRONOMY ran a few years ago ("Build a Binocular Sky Scanner," February 1988), I built a binocular holder with a first surface mirror and have it mounted on a tripod. It greatly aided in the search for Comet Austin and gives tremendous views of clusters, nebulae, and the Milky Way. Again, portability is the key. My 10x50 binocular is very light — the entire setup tips the scales at a mere five pounds. As with the telescope, by using a camera strap attached to the tripod, I can sling the binocular viewer over my shoulder and get to the observing site with my crutches. This equipment would serve me very well should I ever need a wheelchair. I could place the tripod over the chair's arms, use a bungee cord to hold it in place, and roll out to the site. I borrowed a chair to test my theory and found that this does work

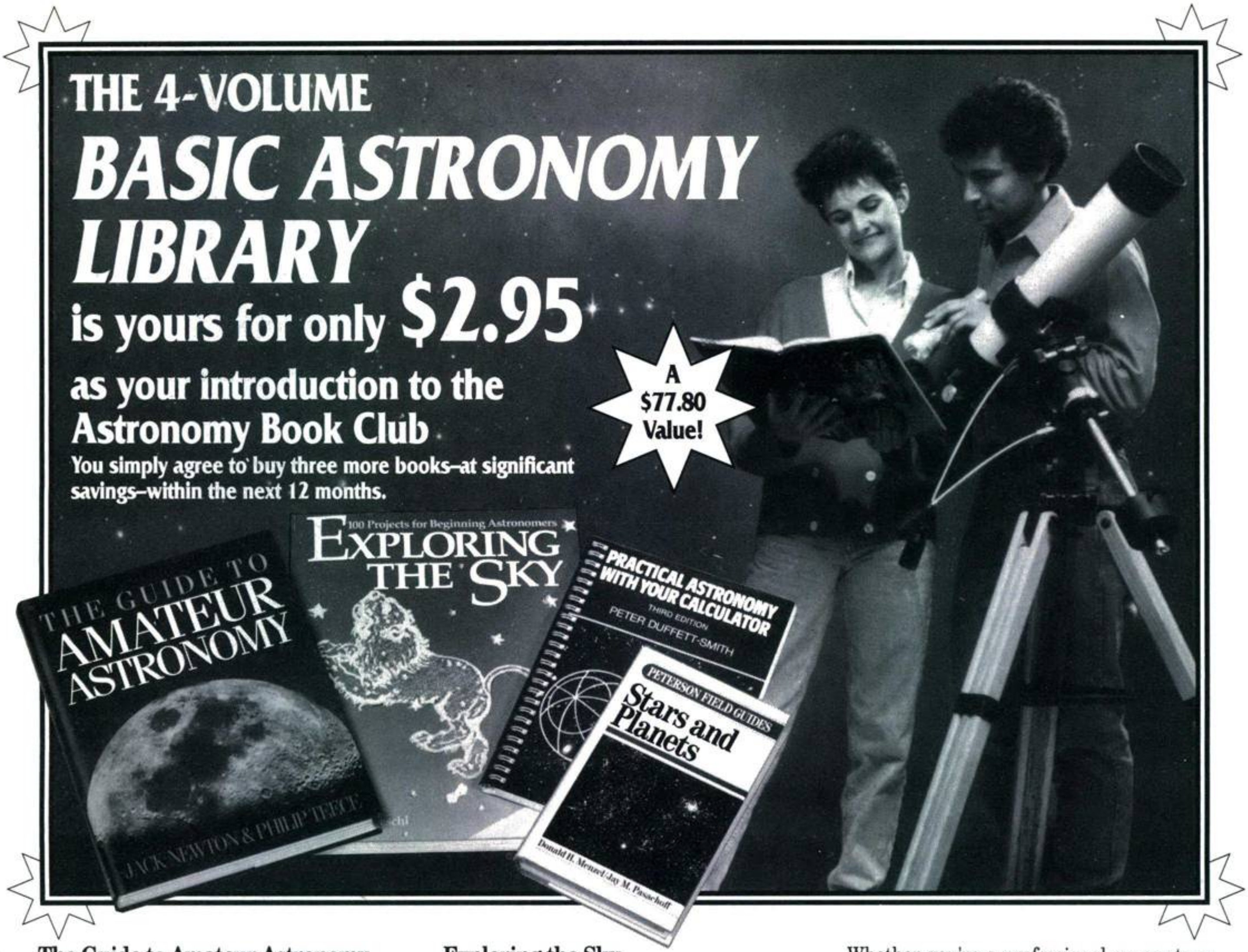
I've also learned that preparation is extremely important. In the early spring and late fall, the temperatures here in central New York drop into the mid and low 30s late at night. Since my lower extremities don't have the strength and circulation that most people's do, I found it necessary to dress a bit warmer than others would. A blanket, folded and placed over my lap, is helpful in keeping me warm enough to observe in comfort. Should I get to the site and find that it isn't as cool as I thought, I can also place the blanket over my head and the eyepiece to keep any stray light from interfering.

Since it takes me a bit longer to prepare for an observing session, I use the time to decide just what objects I want to observe. I also pick an alternate in case the primary object isn't available either because I've arrived too late or there is a cloud bank obscuring my view. This planning streamlines the entire evening, allowing me to see more each time I go out.

My personal experiences have shown me that people with disabilities can become involved in astronomy. More and more, I hear about clubs such as the Syracuse Astronomical Society and individuals like Denise Sabatini making their observatories accessible to people with disabilities. This is very encouraging, and I would offer some other suggestions to those who wish to make the sky accessible to everyone.

- Contact a local group that advocates for people with disabilities to see if they can assist your group by getting the names of those interested in becoming involved in astronomy.
- Listen to those people who express an interest. They are your best source of information about what might be needed to make your site more accessible and enjoyable for those with limited mobility.
- Use telescopes with eyepieces that are closer to the ground, like refractors. Equip telescopes with tripod legs that are adjustable in height so that those who don't have chairs can view comfortably by raising the eyepiece to their height.
- Have an accessory table or tray at a convenient location so filters, eyepieces, or charts can be within easy reach with a minimum of stretching.
- Keep a supply of knit caps and warm blankets at your site to assist anyone who forgets just how cold it can get around midnight or 2 a.m.
- Have a cooler or thermos on hand (with disposable cups) for anyone who needs to take medication. You might even want to have a designated "clock watcher" on hand to ask if any of your visitors are taking medication and then, through the night, to remind those people to take it. It's very easy to get caught up in a viewing session and lose all track of time.

These are a few of simple and inexpensive ways I've found to make a viewing session or site more enjoyable for everyone. When I first became disabled, I was afraid that my pursuit of astronomy would be confined to indoors. However, my disability has taught me (and my able-bodied friends) much more about my *abilities*. It's a lesson from which I hope others can benefit. We who have disabilities represent a huge pool of talent and interest just waiting to be tapped. Let's make the 90s the decade of making the universe accessible to all.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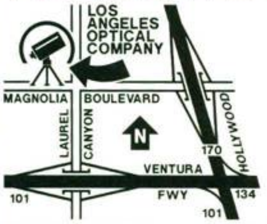

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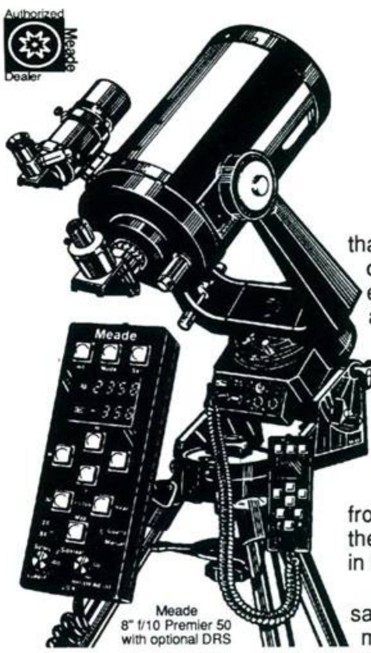

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REDISCOVERING AN OLD FRIEND

by Carol Loveridge

As I was walking my dog on a clear, crisp November day last year a thought came to me that would never have occurred to me a couple of years ago. It made me realize how my interest in astronomy has affected my life. I thought to myself, "I probably won't get out with my telescope for a couple of weeks because of the Moon." I must admit up front, I am a deep-sky enthusiast. Yes, I did get out several times to observe Mars last fall, but now the lure of astronomy for me is trying to find elusive deep-sky objects from a dark site.

Like many amateur astronomers, my interest began when I was a teenager. I read everything I could find at the local library, subscribed to an astronomy magazine, and learned to identify the constellations and bright stars. In those days, the stars became familiar friends.

Since my parents were not interested in astronomy I could only dream of having a real telescope. I remember cutting out a full page ad for a 6- or 8-inch reflector with an equatorial mount and clock drive and dreaming over it like other teens drooled over pictures of the Beatles or the Rolling Stones. At that time, as I recall, the price was an astronomical $199. Unable to afford such a luxurious telescope, I ended up secretly ordering a cheaper telescope — a

3-inch reflector on a wobbly mount from the Sears catalogue for $39. When I was found out by my parents, I promised to pay them back out of my 50¢-per-week *allowance* so I would not have to return it.

However, despite its many flaws I saw a lot with that little scope. I clearly remember looking out my bedroom window at the fuzzy ball of stars that was M13. In the late 1960s you could still see such things in downtown Toronto. Goodness knows what the neighbors must have thought the telescope was pointed at.

More than anything I wanted to become a professional astronomer. There were a few drawbacks — mainly my inability to understand math, physics, and especially calculus, even at the high school level. When I joined the high school astronomy club (as the only girl) no one was more surprised than my physics teacher who ran it. Was there hope for me after all?

I went on to university but took a science degree in biology, not math and physics. By then, my telescope was gathering dust in a closet.

Twenty years later I chanced upon a copy of ASTRONOMY magazine at the newsstand of our local pharmacy. It was a turning point. I had rediscovered an old friend. Although I had read some astronomy news over the past two decades, I began to realize what tremendous advances had been made in astronomy since I was a teenager, and how much I had missed, and that the future technology would bring in a flood of knowledge to those whose eyes and minds were open to receive it. Over the past two years, I've avidly begun reading books,

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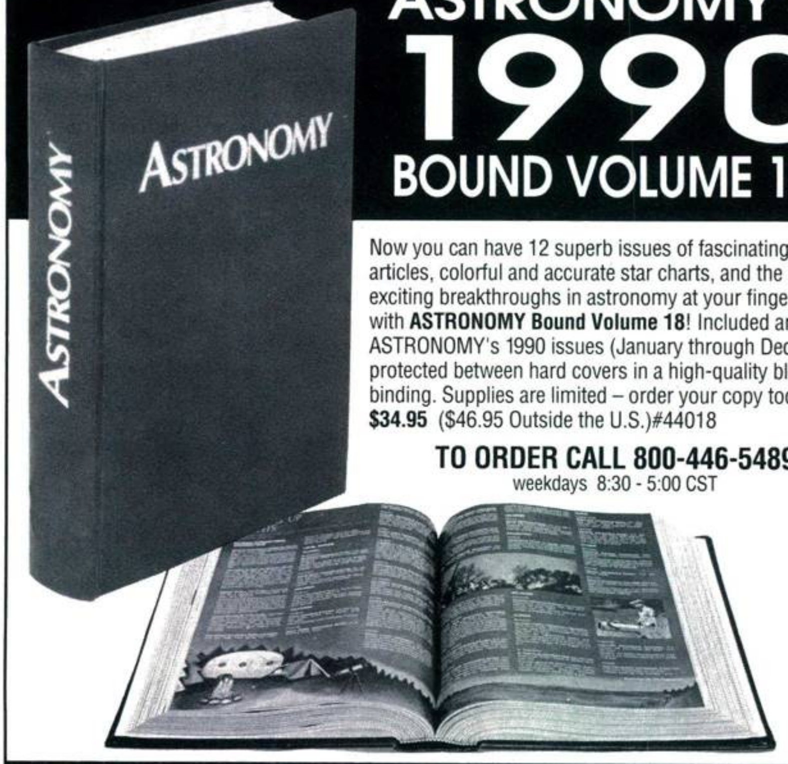

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joined the Astronomy Book Club, subscribed to all the astronomy magazines, and begun to reacquaint myself with the night sky.

A year ago, I dusted off the old 3-inch reflector for the first time in two decades and set it up on the front lawn of our farm. One hundred miles from the nearest city and with a clear view in all directions, I had no trouble finding M81 and M82 in Ursa Major and the Whirlpool Galaxy, M51, in Canes Venatici. After reading stories about city astronomers lugging their 100 pounds of gear down four flights of apartment stairs and then driving for two hours to a dark-sky site, I realized how lucky I was to live in a rural area. It was time to make my dream of 20 years come true.

Although that 8-inch reflector costs considerably more today, I am now the proud owner of an 8-inch Schmidt-Cassegrain. Despite a lot of cloudy weather over the winter I've been able to get out a dozen times, accompanied by Mozart, Beethoven, or Bach. I'm beginning to figure out how to use my telescope efficiently despite the "user-friendly" manual it came with, and star hop from globular cluster to galaxy, even though what I see through the eyepiece is not the same orientation as depicted in my star atlas.

In the summer it's a battle with mosquitoes and late sunsets, and in the winter frost builds up on everything. Still, I've seen sights that no one I know could even imagine exist. When I succeed in finding a galaxy that I've never seen before, the knowledge of what that "faint smudge" really means keeps me going. It doesn't even bother me that my husband calls it "just another faint smudge." I know that faint smudge is a vast galaxy of stars with planets possibly teeming with life.

There is a lifetime of viewing pleasure out there for those of us with the "astronomy bug." Looking back over the last 20 years I wish I'd kept up with my hobby for I feel I've an awful lot to learn again. My advice to aspiring astronomers and keen teenagers is — keep with it no matter what. There are few greater thrills than the realization that those photons of light hitting your eye alone have been traveling for millions of years.

I now eagerly await the return of the spring stars so I can get my first views of the galaxies running through Virgo and Coma Berenices. After being away from them for so long, it's nice to back among the friendly stars. ☐

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BAUSCH & LOMB DISCOVERER

DISCOVERER with 15-60x Zoom	**169.^{95}**
Discoverer Case	**44.95**
Tamrac Case for Discoverer	**19.95**
Camera Mount	**19.95**
Car Window Mount	**34.95**

Bausch & Lomb 800mm Mirror Spotting Scope

800 f/10 Compact Unit (only 8" long)	**219.95**

SPACEMASTER (60mm)

Spacemaster	**136.95**
Spacemaster Rubber Armored	**146.95**
Spacemaster with 15-45x, Tbl Trpd. and Case	**224.95**
Spacemaster RC w/15-45x & Tbl Trpd. and Case	**244.95**
Spacemaster Waterproof w/15-45x & Hrd Case	**329.95**

SPACEMASTER II (70mm)

Spacemaster II	**159.95**
Spacemaster II with 15-45x, Tbl Trpd. and Case	**244.95**

Spacemaster 60/70 Access.

15, 20, 25, 40 & 60x EP.	**36.95**
22x Wide Angle	**41.95**
15-45x Zoom Eye Piece	**84.95**
Camera Mount	**29.95**

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Waterproof & Multi Coated

ELITE with 15-45x Zoom Eyepiece	**329.^{95}**
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ADORAMA'S IN HOUSE REBATE OFFER

Did you lose out on the greatest Tele-Vue Plossl give-away **Do not despair**, Adorama is now offering its own giveaway. For each Plossl eyepiece (up to 26mm) purchased we will give you the second Plossl eye piece (up to 26mm) for 30% off our always low price.

NEW PLOSSL

55mm 2"	**Call**
40, 32mm 1 1/4"	**Call**
26, 21, 17, 13mm 1 1/4"	**Call**
10.5, 7.4mm, 1 1/4"	**74.95**

NEW WIDEFIELD

40mm 2"	**Call**
32mm 2"	**Call**
24mm 1 1/4"	**Call**
19mm 1 1/4"	**Call**
15mm 1 1/4"	**Call**

NAGLER

20mm Type 2; 2"	**Call**
16mm Type 2; 2, 1 1/4"	**Call**
12mm Type 2; 2, 1 1/4"	**Call**
13mm 2" & 1 1/4"	**Call**
9mm 2" & 1 1/4"	**Call**
7mm 1 1/4"	**Call**
4.8mm 1 1/4"	**Call**

BARLOW

2.5X, 1.8X 1 1/4"	**Call**
Big Barlow 2x 2"	**179.95**

ACCESSORIES

2" Star Diagonal	**139.95**
Rich Field Kit w New 55 Plossl 2" S.D., Adapt, 2" to 1 1/4" Adapt	**344.95**
1 1/4" E.P. Adapter f Questar	**59.95**

PARACORR COMA CORRECTORS

1 1/4"	**169.95**	2"	**279.95**

TELEVUE REFRACTOR

UPGRADED! Genesis 4" (101mm) f 5 Fluorite APO The Ultimate Refractor	**Call**
ORACLE 3" (7mm) f 7.4	**Call**
RENAISSANCE 4" f 5.5 Brass Refractor	**Call**

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TV Panoramic w/Wood Tripod Alt-Azimuth Mount	**349.95**
New Tele Pod Alt Azimuth Mount	**229.95**
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New! **Starbeam** ."Red Star" Projection Finder	**Call**
New! **Piggy-Cam** .Camera Adapter	**Call**

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Edmund Scientific's affordable wide-field, go-anywhere telescope gives super bright images.

RKE Eyepieces 1 1/4"	**39.95**	R.A. Prism Erector	**44.95**
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3" f/6 Reflector	**179.95**		

TELESCOPE ACCESSORIES

OMNICON
Collapsible Dew Shields
Fold down easy to store

for Celestron C90	**18.95**
for Meade 2045	**18.95**
f/8" Schmidt Cassegrains	**28.95**
f/10" Schmidt Cassegrains	**38.95**

Schmidt Cassegrain Photo Adapters

Tele Extender for Eyepiece projection photography. Fits Celestron / Meade	**24.95**
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Heavy Duty Rechargeable DC Power Pack

5 Amp Unit	**69.95**
12 Amp Unit	**89.95**

Eye Piece Adapters

Eye Piece Size		Focuser Size	
2"	to	1.25"	**24.95**
1.25"	to	.96"	**19.95**
.96"	to	1.25"	**19.95**

Off Axis Guider System

- Features off axis guider body
- 12.5mm Orthoscopic 1.25"
- illuminated cross hair reticle ,
- self contained battery. No dangling wires from eyepiece

All for only **169^{95}**

CELESTRON®

SCHMIDT CASSEGRAIN TELESCOPES

New Ultima 8 P.E.C. (Periodic Error Correction)	**1899.95**
New Ultima 11 P.E.C. (Periodic Error Correction)	**3299.95**
Focus Motor for Ultima P.E.C.	**139.95**
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New Powerstar 8 P.E.C.	**1549.95**
CLASSIC 8 with SBC	**1019.95**
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Single Axis Drive for Super Polaris	**154.95**
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New Advanced Astro Master (f/fork mounted C8s & SP Mounts)	**499.95**

COMA CORRECTOR

With 1$^1/_4$", 2" Eyepiece & Focus Adapter	**179.95**

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f/6.3 Focal Reducer Corrector only	**144.95**

NEW 2" PRISM DIAGONAL

New 2" Prism Star Diagonal w/1.25" adapter, T-adapter f/new medium format & 35mm cameras	**269.95**

NEW Medium Format T-Adapter System

T-Adapter 6x6	**59.95**
T-Rings f/most Med. Format Cameras (Hasselblad, Pentax, Mamiya)	@ **159.95**

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Super Polaris 6" (SPC 6)	**719.95**
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Polar Axis Finder w/Illum f/SP Mounts	**74.95**
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REFRACTOR TELESCOPES

Super Polaris C102 102mm	**1047.95**
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60mm Altazimuth	**136.95**
60mm Equatorial Only	**199.95**
Correct Image Eyepiece f/60mm Ref	**16.95**
T Adapt/Tele Extender f/60mm Ref	**43.95**

SPOTTING SCOPES

All the C90s Include: 8x20 Erect Image Finder, 45° Erect Image Diagonal, 30mm, .96" E.P., Foam Fitted Case

C90	**368.95**	C90 MC	**398.95**
C90 Rubber	**389.95**	C90 Rubber MC	**444.95**
New **C90MC** w/1.25" Accs.	**499.95**		
New **C90MCRC** w/1.25" Accs.	**549.95**		
1 1/4" Super C90 Upgrade Kit	**154.95**		
C65 Rubber Coated	**197.95**		
C60 Rubber Coated	**259.95**		
Zoom Master II	**294.95**		
SS-80 w/45° Erector, 18mm 1.25" E.P.	**309.95**		
500mm f5.6 Lens	**209.95**		

SPECIAL OFFER
Celestron C-90 Spotting Scope Accessory Kit
Consists of 1 18mm .96 Kellner (55X) • 1 10mm .96 Kellner (100X) • T-Adapter C-90. A $138 retail value for only **59.95**

CELESTRON C90 & SPOTTING SCOPE ACCS.

Barlow .96, 2.5,	**26.95**	Series 5 Filter Set	**59.95**
5,6,7,9,12 Ortho, .96	**37.95**	Skylight Filter #1	**34.95**
10,16, 18, 25, 30, 40 Klnr.96	**33.95**	Deluxe Slow Motion Ctl	**46.95**
Mult Ocular .96 Hold	**69.95**	T Adapt. C90	**29.95**
Porro Prism .96	**44.95**	New Photo Tripod	**109.95**
Diag Prism 45° .96	**47.95**	Shoulder Mount	**69.95**
Diag Prism 45° .96 to 1 1/4	**49.95**		

CELESTRON TELESCOPE ACCS.

New Improved Accs Cs.	**44.95**	Off Axis Guiding Sys	**169.95**
Binocular Viewer	**449.95**	Piggyback Mt 8"	**36.95**
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Barlow 2" 2x	**89.95**	Polarizer Filter Assm	**89.95**
Barlow Lens 1.25" 3X	**32.95**	Polarizer Set 1 1/4"	**49.95**
Counterwt Bar Assm 8"	**114.95**	Porro Prism 1 1/4"	**49.95**
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45 Erect Prism 1 1/4"	**52.95**	Super Polaris 8" Mount with Polaris Finder	**549.95**
Dewstar/Shade 8"	**27.95**	Sky Filter #2	**39.95**
8x50 RA Pol Find C8	**149.95**	Diagonal with 1.25" Adapter	**144.95**
Focus Motor 11, 14	**119.95**	Adj. Tripod Rubberized	**209.95**
Illum Proj Reticle 1 1/4"	**149.95**	Tele Extender	**29.95**
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LPR #B (Rear Cell)	**109.95**	Vibration Suppr. Pads	**44.95**
LPR Filter #C (f/2" E.P.)	**139.95**	Wedge f/C8	**87.95**
Micro Guide Eyepiece	**149.95**	New Tilt -Plate 0°	**79.95**
Mult Ocular Hldr 1 1/4"	**124.95**		

CELESTRON 2", 1$^1/_4$" & .96" EYEPIECE FILTERS

(Not all filters available in .96" & 2")

Available in the following colors: 1A Skylight; 8 Yellow; 12 Deep Yellow; 15 Deep Yellow; 21 Orange; 23A Red; 25 Red; 38A Blue; 47 Violet; 56 Light Green; 58 Green; 80A Light Blue; 82A Pale Blue; ND 0.3; ND 0.6; ND 0.9 Polarizer

.96" & 1.25"	**Each 14.95**	2"	**Each 29.95**
Buy any 4 filters (.96"or 1.25") **for only**	**44.95**		

CELESTRON MYLAR SOLAR FILTERS (MOUNTED)

f/60 Ref	**43.95**	f/80 Ref	**47.95**	f/C90s	**69.95**	f/C90s Rlc	**84.95**
f/c4.5	**69.95**	f/C102	**84.95**			f/C8s	**114.95**

CELESTRON 1$^1/_4$" EYEPIECES

5, 6, 7, 9, 12mm, Ortho	**49.95**	22, 30 Plossl	**76.95**
20,24mm Erfle	**49.95**		
Zoom Ocular (8.4-21mm) Ortho	**108.95**		

NEW ULTIMA EYEPIECES

5, 7.5, 12.5, 18, 24mm, 1 1/4"	**64.95**		
30, 35, 42mm 1$^1/_4$"	**89.95**	15,19,23mm W.A. 1$^1/_4$"	**114.95**
45, 60mm 2"	**167.95**	80mm 2"	**269.95**
Ultima 2X Barlow	**64.95**		

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No Surcharge for MasterCharge or Visa Purchases. Personal checks welcome, will ship without delay. Name must be imprinted on check, also include address, phone, and a copy of major credit card or driver's license for reference. Shipping, handling and insurance additional. 14 day money back guarantee less shipping, with packing and blank warranty card, except film and paper. We ship UPS. Some items special order. All orders are subject to acceptance and verification. Second hand dealer's license #802862. Pictures are for illustration purposes only and may not be exact. **Prices effective till April 3, 1991** **Please address all inquiries and orders to ASTRO. DEPT. #55**

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Orion® SpaceProbe™ 4.5" Equatorial Reflector

NEW!

Our new 4.5" f/8 reflector gathers 3.6 times more light than 60mm telescopes; twice as much as 80mm models; ideal for deep space observation. Full featured equatorial mount with slow motion controls & setting circles. Achromatic 6x30 right angle finder and two eyepieces: 25mm (36x) and 9mm (100x). Deluxe hardwood tripod and accessory tray. Compare our price!

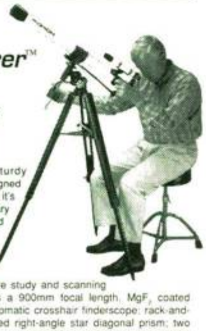
#9097 **$399** (18.73)

Orion® TeleVista™ 60mm Altazimuth Refractor

This affordable telescope is equally at home viewing the rings of Saturn or boats across the bay. One of our most popular sellers, it will provide you with years of viewing enjoyment. Includes a quality coated 2-element achromatic objective lens and two quality Kellner .965" eyepieces, 25mm & 9mm, for sharp, clear images at 28x and 78x. Sturdy all metal optical tube and yoke mount, plus strong adjustable wooden tripod, smooth focuser and diagonal prism. A great, economical choice for observers of all ages.

Best Buy! #9091 **$169** (9.90)

Orion® Sky Explorer™ 60 Equatorial Refractor



The Sky Explorer's sturdy equatorial mounting is designed specifically for astronomy; it's ideal for lunar and planetary study, while providing good views of nebulas, star clusters, and double stars. By day, it's a powerful terrestrial telescope, great for nature study and scanning distant vistas. It features a 900mm focal length, MgF_2 coated objective lens; 6x30 achromatic crosshair finderscope; rack-and-pinion focuser, fully coated right-angle star diagonal prism; two quality fully coated Kellner eyepieces, 25mm (36x) and 9mm (100x); all metal equatorial mounting; worm gear slow-motion control knobs, celestial coordinate setting circles; dual flexible control cables; adjustable counterweight; adjustable deluxe hardwood tripod; and lighted accessory tray.

#9092 **$329** (12.70)

Orion® Big Eye 8x50 & 11x80 Finder Scopes

NEW!

Ideal for upgrading any telescope including Schmidt-Cassegrains. Available non-illuminated or with wireless, adjustable, battery-operated illuminated reticle and Polaris grid for accurate polar alignment. With 90° diagonal prisms. Optional deluxe dual-ring brackets are perfect for 8" and 10" Celestron or Meade; will fit many others, too.

8x50 Models The 50mm objectives gather 2.7 times more light than 30mm finders!

8x50 Standard Finder #7100 **$89.95** (3.31)

8x50 Illuminated Finder #7135 **$134.95** (3.56)

Bracket— For 8" & 10" #5143 **$25.95** (1.89)

11x80 Models These huge finders gulp in over 7 times the light of 30mm finders; 2.5 times more than 50mm models! You might spend more time viewing through the finder than through your main telescope!

11x80 Standard Finder #7146 **$219** (4.16)

11x80 Illuminated Finder #7143 **$269** (4.16)

Bracket— For 8" & 10" #5140 **$37.95** (2.39)

SuperGiant™ 14x100 Binoculars

NEW!

Gigantic 100mm (almost 4 inch!) lenses gather 156% of the light of 80mm binoculars. Individual eyepiece focus improves alignment and allows for more precise focus. They feature Fully Multi-Coated optics and BAK-4 prisms. Comes with the integral platform tripod mounting plate and metal-clad case. 14x magnification, field of view 3.3°, exit pupil 7.0mm, weight 7.5 lbs., height 13.5".

#9495 **$799** (12.95)

Orion® Enhanced™ Giant Binoculars

20% more light transmission than ordinary "fully coated" binoculars. Fully Multi-Coated optics and superior BAK-4 prisms provide fantastic contrast and greatly improved edge sharpness.

11x80 MC- Brightest, widest-field available. Ideal for deep-space observation under dark skies. Hand-holdable.

#9502 **$349** (6.43)

16x80 MC- 45% higher power, excellent for astronomy and daytime observation. Tripod recommended.

#9496 **$379** (6.43)

20x80 MC- Highest power model perfect for smaller deep-space objects and long range daytime views. Tripod required.

#9498 **$389** (6.43)

Orion® Little Giant™ 9x63 Roof Prism Binoculars

Popular mid-sized binocular, Fully Multi-Coated and remarkably lightweight. Excellent contrast and sharpness at center of field, with enough power to see lunar craters & Jupiter's moons. 5.5° field of view. Weight 2.8 lbs.

#9500 **$199** (4.80)

Orion® Sky Explorer™ Mini Deep Sky 8x56 Binoculars

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view.

#9504 **$139** (4.16)

Superior Performance 7x50 Adlerblick Binoculars

Incredible wide field eyepiece design, Fully Multi-Coated, BAK-4 prisms, and best special glass objective lenses make the 7x50 Adlerblick the archrival of European brand binoculars selling for 3-4 times the price. Orion buys direct, saving you money. Includes deluxe hard case, lens caps, straps.

#9612 **$269** (4.16)

Orion® 7x50 Observer™ Binoculars

NEW!

Our new Observer binocular is an ideal moderately priced night-vision binocular for both astronomy and general purpose daytime observation. Fully coated optics with a 7° field of view, and a bright 7mm exit pupil. Rugged ribbed rubber covering for a good grip.

#9620 **$84.95** (3.66)

StereoScope™ Binocular Viewing Expander

NEW!

Open up a new dimension in observation! The stereo effect of this viewer is astonishing. Viewing is more comfortable and it shows more detail, especially of the moon and planets. Specially built for astronomical telescopes, features a fully adjustable 55-75mm interpupillary distance scale and a highly precisce beam splitter which maximizes transmission of light to each eyepiece and equalizes the brightness of each image. Threads securely onto any Celestron or Meade Schmidt-Cassegrain. Includes a thread-on matched 2x Barlow lens. (Shown with two eyepieces, not included.)

#9720 **$399** (3.79)

Orion® 12.5mm Plössl Illuminated Reticle Eyepiece

NEW!

This new 12.5mm 4-element Plössl offers unprecidented eye relief and observing comfort during long astrophoto exposures. The battery operated integral illuminator has fully adjustasble brightness. Features double crossline reticle.

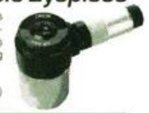
#8484 **$99** (2.79)

World's Finest Illuminated Reticle Eyepiece

6mm Orthoscopic design for required high-power guiding, plus unique X-Y adjustable reticle positioning for easy guide-star alignment. Wireless LED illuminator has adjustable brightness.

#8487 **$139** (2.79)

Orion® 9mm Orthoscopic Illuminated Reticle Eyepiece



9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.

#8488 **$119** (2.79)

Orion® 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into LX/3, LX/5 and Premier drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.

#8482 **$69.95** (2.59)

Orion® 2" Barlow Lens

NEW!

2x magnification, Multi-Coated, 2-element 40mm diameter achromatic lens. Baffled to eliminate off-axis glare. Works with all 2" barrel diameter eyepieces. Chrome plated brass barrel and blackened aluminum body with knurled set screw.

#8720 **$69.95** (2.59)

Orion® VariPower™ 2-3x Multi-Coated Barlow Lens

Our best barlow offers significant improvement over other models we've seen. The magnification is adjusted by sliding the internal lens cell along a calibrated scale (you don't have to poke a finger or pencil inside to do this). Fully Multi-Coated optics provide excellent sharpness, contrast and brightness. 1.25" diameter.

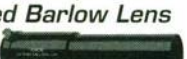
#8748 **$69.95** (2.59)

Orion® 3-element Fully Multi-Coated Barlow Lens

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

#8750 **$59.95** (2.59)

Orion® Deluxe Fully-Baffled Multi-Coated Barlow Lens



Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.

#8746 **$49.95** (2.39)

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77° Field UltraScan Wide-Angle Eyepieces

NEW!

Unlimited visibility is yours with up to 77 degrees of field to catch your eye. High quality optical materials and superb coatings, for the ultimate in contrast and resolution.

1.25" UltraScan Eyepieces
Five optical elements utilizing the latest high refractive-index optical glass materials achieve extremely wide fields with fewer elements than many competitive eyepieces, reducing weight and cost. Each lens surface is fully Multi-Coated, for the ultimate in contrast and elimination of stray reflections. Integral rubber eyeguards.

9mm-#8420 **$99** (2.79), *12mm*-#8421 **$109** (2.79)

15mm-#8422 **$129** (2.79), *19mm*-#8423 **$139** (2.79)

2" UltraScan Eyepieces
These incredible oculars provide breathtaking panoramic, bright views that will astonish you!

30mm 2" UltraScan Eyepiece–This 5-element, 77 degree field UltraScan eyepiece combines the widest possible apparent and true fields with a larger image scale than our 40mm.

#8424 **$199** (2.79)

40mm 2" UltraScan Eyepiece - Orion's brightest, widest true-field UltraScan eyepiece utilizes a sophisticated 7-element design, providing a 68 degree apparent field; the widest we could fit into the 2" diameter barrel.

#8425 **$179** (2.79)

High Resolution Orion® Ultrascopic Eyepieces

Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Compare with other brands selling for much more!

Wide Field 5-element

35mm #8560 **$89.95** (2.59)

30mm #8562 **$79.95** (2.59)

25mm #8564 **$64.95** (2.59)

Medium-High Power 5-element
20mm #8566, 15mm #8568, 10mm #8570, 7.5mm #8572

$59.95 ea. (2.59)

High-Power 7-element 5mm #8574, 3.8mm #8576

$79.95 ea. (2.59)

Orion® MegaVista™ 1.25" Wide Angle Eyepieces

Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye-relief.

10.5mm- An incredible 67° field for outstanding planetary or deep space performance.

#8552 **$109** (2.79)

16.8mm- Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.

#8554 **$119** (2.79)

Orion® UltraZoom™ 7-21mm 1.25" Eyepiece

The finest zoom you can buy for your 1.25" telescope. An excellent choice for astronomy or terrestrial observing. 65°-35° field.

#8556 **$129** (2.79)

Orion® Explorer Series 1.25" Eyepieces

Remarkably affordable, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

Kellner Eyepieces-
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512

$33.95 ea. (2.19)

Orthoscopic Eyepieces-5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526

$46.95 ea. (2.19)

Orion® Explorer Series .965" Eyepieces

Get the most from your small telescope with these fine Multi-Coated eyepieces. Standard .965" barrels fit all Japanese standard small telescopes.

.965" Orthoscopic Eyepieces-
5mm #8580, 7mm #8581
9mm #8582, 12.5mm #8583

$37.95 ea. (2.19)

.965" Kellner Eyepieces
18mm #8584, 25mm #8585

.965" Achromatic Huygenian Eyepieces- 40mm #8586

$24.95 ea. (2.11)

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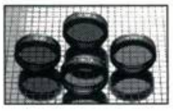

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Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

8" Dew Zappers- fit all Meade & Celestron 8" Schmidt-Cassegrains
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Quality diagonal-cut rack for smooth focusing. Secure slide-fit eyepiece holder. Integral socket for single-stalk diagonal support if desired.

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Large clear diameter ideal for larger scopes and wide-field optics. Precision diagonal cut rack. Long travel for visual and photographic use. Interchangeable 2" and 1.25" holders with set screws.

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Orion® 45-Degree Erect Image Diagonals

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Primarily for astronomical use, lets you view at a right angle. Multi-coated, for 1.25" eyepieces.

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Uses an adjustable extension tube, allowing magnification to be changed without switching eyepieces. Attaches with T-ring, sold separately.

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Standard Universal Camera Adapters
Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately) to match your 35mm camera.

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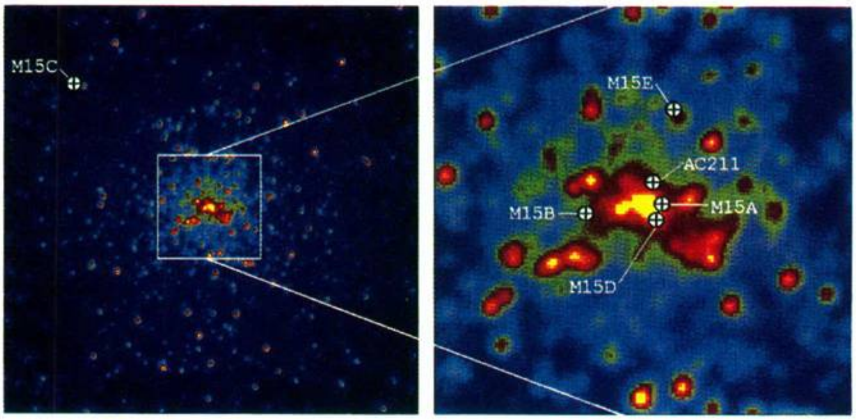

PULSARS IN M15 have revealed that the globular cluster's core must be relatively stable over vastly long time scales — a surprise to astronomers. Photos courtesy S. B. Anderson, Caltech.

Recent results in x-ray astronomy dominated the 1991 winter meeting of the American Astronomical Society, held in Philadelphia, January 13-17. More than 1,400 astronomers from the United States and around the world descended on the Wyndham Franklin Plaza hotel to hear the latest research news. Surprising results came from an array of satellites and telescopes currently in operation and a few instruments — notably Hawaii's Keck telescope — currently under testing.

Nearly a dozen major news stories were announced at the meeting (see below), along with many other progress reports. Invited talks, public lectures, press conferences, and informal meetings rounded out the meeting schedule. Major results came from the world of x-ray astronomy, including preliminary findings from the *Roentgen* satellite and the discovery of a rapidly fluctuating quasar with the *Ginga* satellite. Other satellite observatory reports included an update on *Hubble*, which is a major success despite optical problems, and more results from the *Cosmic Background Explorer*. A coalition of astronomers announced first results from the *Astro-1* mission. Many researchers revealed a slew of other unusual findings in astrophysics and space science. Brief summaries of the most important findings from the meeting follow.

•**Results from the *ROSAT* All-Sky Survey.** The most surprising story came from the *Roentgen* x-ray satellite, which was launched in June 1990 and completed an all-sky survey in February 1991. A collaborative project between Germany, the United Kingdom, and the United States, the *Roentgen* satellite (*ROSAT*) is providing astronomers with x-ray images with a sensitivity 100 times greater than any previous. Moreover, the satellite is the first to directly image diffuse x-ray emission. The result is a flood of discoveries, confirmations, and refinements relating to objects emitting x-rays in the Galaxy and the universe. Among the discoveries are a few dozen previously unknown supernova remnants, one such object lying near the star Capella in Auriga and at a distance of about 3,000 light-years. Also discovered were fifteen new x-ray sources in the Large Magellanic Cloud and odd behavior from pulsars that do not appear to be emitting energy as they should. According to Joachim Truemper of the Max Planck Institute for Extraterrestrial Physics in Germany, "The ROSAT survey is providing us with a completely new look at the x-ray sky."

For nearly 25 years — ever since the discovery of x-rays from outside the solar system — astronomers have wondered why the sky is so bright in diffuse x-rays. *ROSAT* data show that much of this soft x-ray skyglow is coming from huge numbers of very distant quasars. Astronomers still do not know the origin of large amounts of higher energy x-rays, but expect to investigate this matter with sensitive x-ray spectra at a later date. The discovery of the quasar contribution to the x-ray background resulted from a half-day integration with *ROSAT* and is the "deepest x-ray image ever taken," according to Guenther Hasinger also of the Max Planck Institute. "What we see here, for the first time," explains Hasinger, "is a large number of distant quasars enveloped in a diffuse halo of soft x-ray emission." Hasinger explained that these objects have redshifts between 1 and 2, making them extremely distant.

•**Discovered: A Three-Minute Quasar.** American and Japanese astronomers using another x-ray satellite,

"THE ASTRONOMERS" DEBUTS ON APRIL 15

The multi-million dollar television series, "The Astronomers," will premiere on PBS stations on April 15. The six-part series delves into the lives and work of several well-known astronomers. Produced by KCET/Los Angeles, the series makes use of computer-generated special effects to illustrate some of the celestial objects explored by the featured astronomers. As many as 70 different special effects sequences were created to illustrate such exotic phenomena as black holes, quasars, gravity waves, the evolution of the solar system, and the Big Bang.

KECK OBSERVATORY provides a backdrop for Richard Chamberlain (left) and astronomer Kevin Krisciunas in the premiere episode of "The Astronomers."

DANCE OF THE PLANETS

SPACE TRAVEL FOR THE INQUIRING MIND

Dance of the Planets combines subtle, realistic space graphics with accurate orbital simulation and a large object database for the most complete model of the solar system ever created. A solar system of thousands of bodies cruising through three-dimensional space, with motions and interactions determined solely by gravity. Asteroids, comets, and satellites interact with the Sun, planets, and each other producing resonances and precessions. Chaotic comets undergo strong perturbations from Jupiter with intriguing results. Detailed planets rotate. And from the Earth, eclipses, transits, conjunctions, and occultations can be watched from any location.

In addition to the Sun, planets, and 61 known satellites are some 6000 asteroids and comets — virtually all that are known. The **Dance** sky with 9100 stars look genuine. Further out is a selection of over 1300 other interesting objects: galaxies and star clusters, variable stars, pulsars, quasars, and many xray and radio sources.

A deep model of the sky and solar system both graphically and dynamically accurate, a powerful observation and education tool, an orbital lab, **Dance of the Planets** makes it all more meaningfully accessible than ever before.

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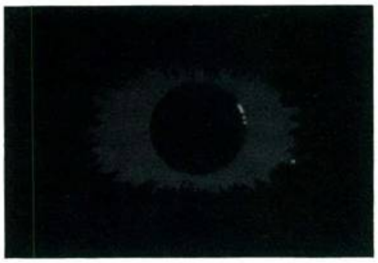
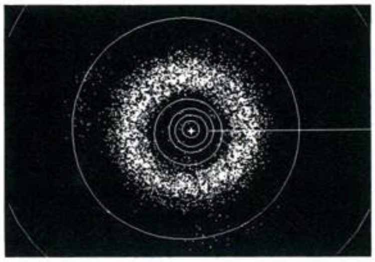
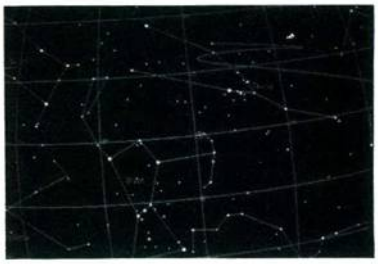
Dance demonstrations are so popular that we have created a special version with 40 interesting menu-selected simulations. A fine introduction to orbital simulation, the **Dance Sampler** is $25 plus shipping, fully credited toward purchase of the full program.



1991 solar eclipse from La Paz.



All the asteroids seen from overhead.



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John Mosley, **Sky & Telescope**, Dec. 1989

This reviewer has encountered no similarly rich entrant in the existing corpus of programs for the personal computer...
Phillip Morrison, **Scientific American**, Sep. 1990

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Ginga, reported the fastest-known quasar eruption. Graduate student Bruce Grossan and Professor Ronald A. Remillard of the Massachusetts Institute of Technology reported that their data, recorded on November 13, 1989, showed a "violent outburst during which the quasar PKS 0558-504 raised its energy output by 67 percent over an interval of three minutes."

The observations, made over 11 hours, are on firm ground despite the fact that only one event was observed. This is because the spike in x-ray emission consists of four separate data points and because other independent detectors on board the *Ginga* satellite showed the same rise in emission. The problem posed to Grossan and his fellow researchers is that such an immense burst of energy must invoke motions in the nucleus of the quasar that approach the speed of light. "Clearly the fast time scale of the eruption tells us the size of the light-emitting region is less than three light-minutes," says Grossan.

However, because of the physical constraints in light travel time and the size of the black hole that must lie in the center of this quasar, the astronomers should not have been able to observe such a burst over only three minutes. Their current hypothesis states that relativistic effects distort the view of the material that makes up the burst of x-ray energy. The quasar's central black hole is emitting a focused beam of material that shoots out of the quasar on two sides. To envision what may have happened, imagine a large chunk of matter falling in toward the black hole and then shooting outward. If the material formed a kink in the jet that happened to be aimed directly toward Earth, then — according to the special theory of relativity — the burst could have appeared "magnified" to us. Astronomers call this effect relativistic beaming and invoke it as the best explanation for the three-minute quasar.

•The Death of Cold Dark Matter? Astronomers reported new results from the *Cosmic Background Explorer* (*COBE*) satellite during the Philadelphia meeting. Launched in November 1989, *COBE* is investigating some of the most fundamental questions in cosmology: Did the universe really begin with a Big Bang? What caused the universe to be uniform on a large scale? What began the process of galaxy formation? The weak radiation that astronomers observe everywhere in the sky is the echo of the primeval explosion that created the universe, and by studying it astronomers hope to detect clues left over like ancient fossils that will resolve these mysteries.

"*COBE*'s latest cosmic background data show that the universe is smooth at very early time scales," says John Mather of NASA's Goddard Space Flight Center. "What we're looking for is any evidence of hot spots and cold spots in the early universe, and have found none. This is strong evidence against the so-called Cold Dark Matter theory that is a component of the Big Bang scenario." (This theory explains how galaxies may have formed from "seeds" in the soup of the early universe.) "All of the speckling we have seen is directly attributable to noise in our instrument," says Mather, "so we can conclude that the universe had no hot or cold spots to the current limit of our data." Cosmologists who have used the Cold Dark Matter theory to explain the evolution of the universe since the Big Bang may have to go back to the drawing board.

•First Results from *ASTRO-1*. Long delayed but finally launched on December 2, 1990, the *Astro-1* mission carried four x-ray and ultraviolet instruments in a payload aboard the space shuttle. Three early images from the mission were released at the Philadelphia meeting. The first is a closeup view showing the central portion of globular cluster Omega Centauri made by *Astro-1*'s Ultraviolet Imaging Telescope (UIT). Isolating and studying the hottest cluster stars should yield information about how stars evolve and die. A second UIT image shows galaxy M81 and its busy star-forming regions; collecting many such pictures will give astronomers a better view of the rates of star formation in normal galaxies. The final image shows a portion of the Veil Nebula, NGC 6992, and its analysis will reveal

Space News

FIXING THE BLAME FOR HST

NASA and Perkin-Elmer must both share the blame for the *Hubble Space Telescope's* flawed mirror. That was the conclusion of the *Hubble* failure review board chaired by Lew Allen, outgoing director of NASA's Jet Propulsion Laboratory. The conclusions come as no surprise, but the board did find that Perkin-Elmer had data from not one but three independent optical tests, each showing that there was a problem with the mirror. Perkin-Elmer failed to act on any of these test results.

The primary test, using a "reflective null corrector" lens, gave erroneous results because of a 1.3 mm error in the spacing of the optical elements of the test array. This flawed null corrector was used to guide the mirror's manufacture, and as a result the mirror was ground incorrectly. However, there were three other opportunities for Perkin-Elmer to catch the mistake: once when extra spacers had to be added to the null corrector to make it work and later during two other optical tests, one with an inverse null corrector and one with a refractive null corrector. Both of these independent tests showed there was a problem but the findings were discounted as unreliable.

The board also pointed to NASA's inability to supervise the fabrication of the mirror. According to the board's report, NASA officials were not allowed to examine the mirror closely during the fabrication process. As the review board noted, the Optical Operations Division of Perkin-Elmer operated "in a closed-door mode. The impermeability of this division seems astounding." In addition, "NASA project management did not have the necessary expertise to critically monitor the optical activities of the program. The record reveals . . . no questioning of test method."

At NASA's request, the review board also examined the quality control for the mirrors for the *Advanced X-ray Astrophysics Facility*. These are being made at Hughes Danbury Optical Systems (formerly Perkin-Elmer) at the same facility where the *Hubble* mirror was made. However, the board found that the problems with management and test procedures evident in the Hubble era have now been cleaned up.

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Fixed Focus Series—Convenient, no focusing required. Fully coated, BK7 prisms. 8x40 WA, 7x50, 10x50 WA.

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•**Surprises Lurk in M15.** Several presentations focused on the globular cluster M15 in Pegasus. A group of astronomers from the California Institute of Technology and the Arecibo Observatory have produced a new map showing the positions of five pulsars in the cluster — two were just discovered, two were discovered in 1990, and one several years ago. The objects have periods ranging from 4.65 milliseconds to 110.66 milliseconds. The binary pulsar designated M15C has apparently been knocked some 8 light-years out from the cluster's center by a violent stellar collision. That several pulsars exist near the cluster's center is puzzling because astronomers would have assumed that these stars, which are ancient binary systems, would not be able to survive for billions of years in the hostile environment of the inner part of a dense globular cluster.

Hubble Space Telescope turned its attention toward M15 last spring and made images of the cluster's heart. The resulting data, presented by astronomers Tod Lauer of the National Optical Astronomy Observatories, Jon A. Holtzman of Lowell Observatory, and Sandra Faber of Lick Observatory, show the cluster's center in clear detail. Containing about a million stars and lying at a distance of 42,000 light-years, M15 is a typical globular cluster. Lauer explains that M15 is currently recovering from an implosion in which the cluster's center collapsed into a dense aggregate. The study also suggests strongly that the cluster does not have a central black hole — for many years astronomers suspected it did.

•**Hydrogen Plumes Found near Peculiar Galaxy.** Two long plumes arcing away from the peculiar galaxy NGC 2782 have been discovered by astronomer Beverly J. Smith of the University of Texas at Austin. Smith detected the plumes of neutral hydrogen by measuring radio-wavelength emissions of the galaxy at 21 centimeters wavelength, using the Very Large Array radio telescope in New Mexico. The plumes contain 5.1 billion solar masses of hydrogen, about 70 percent of the material associated with the galaxy. "The double-plumed structure and the difference in length of the plumes suggest that NGC 2782 is the result of a merger of two galaxies of unequal mass," says Smith.

•**Progress Reported after Keck's First-light Image.** Following the first-light image made by the Keck telescope in November 1990, project scientist Jerry Nelson reported that all is well for what will be the world's largest telescope at the end of 1991. Situated high atop Mauna Kea in Hawaii, the Keck telescope will consist of 36 mirror segments each individually steered to produce a single, 10-meter mirror. (The first-light image was made in November because at that time the telescope approximately matched in light-gathering power the Hale telescope in California, and observers wanted to compare image quality.) Nelson reported that the telescope is on schedule. Seeing in the Keck dome is reportedly better than that in other domes on Mauna Kea, and test images bear that out. The standing-room-only crowd at the Keck presentation was overjoyed at the report — they knew that they were hearing about what will be the Palomar Observatory of their time.

•**Astronomy Is "On the Threshold of a Golden Age."** D. Allen Bromley, President Bush's science advisor, delivered a public policy lecture in which he outlined his views on the future of professional astronomy and NASA's astronomical projects. "I was particularly impressed by the Keck telescope — it is a technological *tour de force*," says Bromley. "Astronomy is on the threshold of a golden age," Bromley added, quoting members of the advisory committee of the National Science Foundation. Bromley feels that space-based and ground-based astronomy will continue to gain momentum and be a vital part of American science and that astronomers need to become more involved with pushing for funding and project starts. "Astronomers are afraid of politics," he says, "but you cannot be — it is the method by which modern science begins." □

Amateur News

THE 1990 RADIO-VIDEO STAR PARTY

The 1990 Okie-Tex Star Party may have been the world's first intercontinental, interhemispheric star party. Two star parties, one in Oklahoma and one in New South Wales, Australia, shared ham radio communication and a slow-scan TV link.

First a bit of background. Okie-Tex began seven years ago as a way to bring together amateur astronomers in Oklahoma City and Dallas. (It is held in the fall, about six months after the Texas Star Party.) Since that beginning Okie-Tex has grown into one of the significant events on the observing calendar. In 1990, the Okie-Tex Star Party took place on September 18 to 22, drawing some 200 amateur astronomers from about a dozen states.

Okie-Tex began rather inauspiciously: in each of the first two years more than two inches of rain fell and people started to call it the Soakie-Tex Star Party. In 1990 skies were clear for the early arrivals on Tuesday, the 18th, but clouds began rolling in on Wednesday afternoon. Observers who played tag with them that night got in some viewing anyway. Before the clouds settled in solidly, David Higgins, contributing editor of *Deep Sky* and one of the featured speakers, showed off a few of the globular star clusters in the Andromeda Galaxy, M31.

This year's Okie-Tex held a special attraction. Just a month before Okie-Tex began, the Oklahoma City Astronomy Club received a letter from Chris Mlynarik of the Astronomical Society of New South Wales. The Australian group was planning to hold its annual Mt. Kaputar Star Party at the same time as Okie-Tex. Several of its members are also ham radio operators. Chris inquired about the feasibility of a radio linkup between the two star parties and suggested the possibility of slow-scan TV transmission.

We managed to carry out virtually all the planned voice contacts. But because of the Australians' low broadcast power, the images they sent weren't received very clearly at our end. They received our images well enough, however, including a warm Okie-Tex "Howdy!"

We are planning to hold this planet-wide party annually. — *Wayne Wyrick.*

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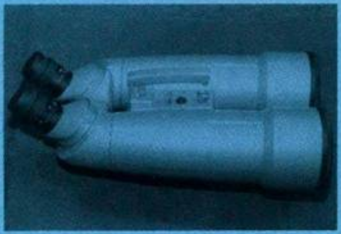

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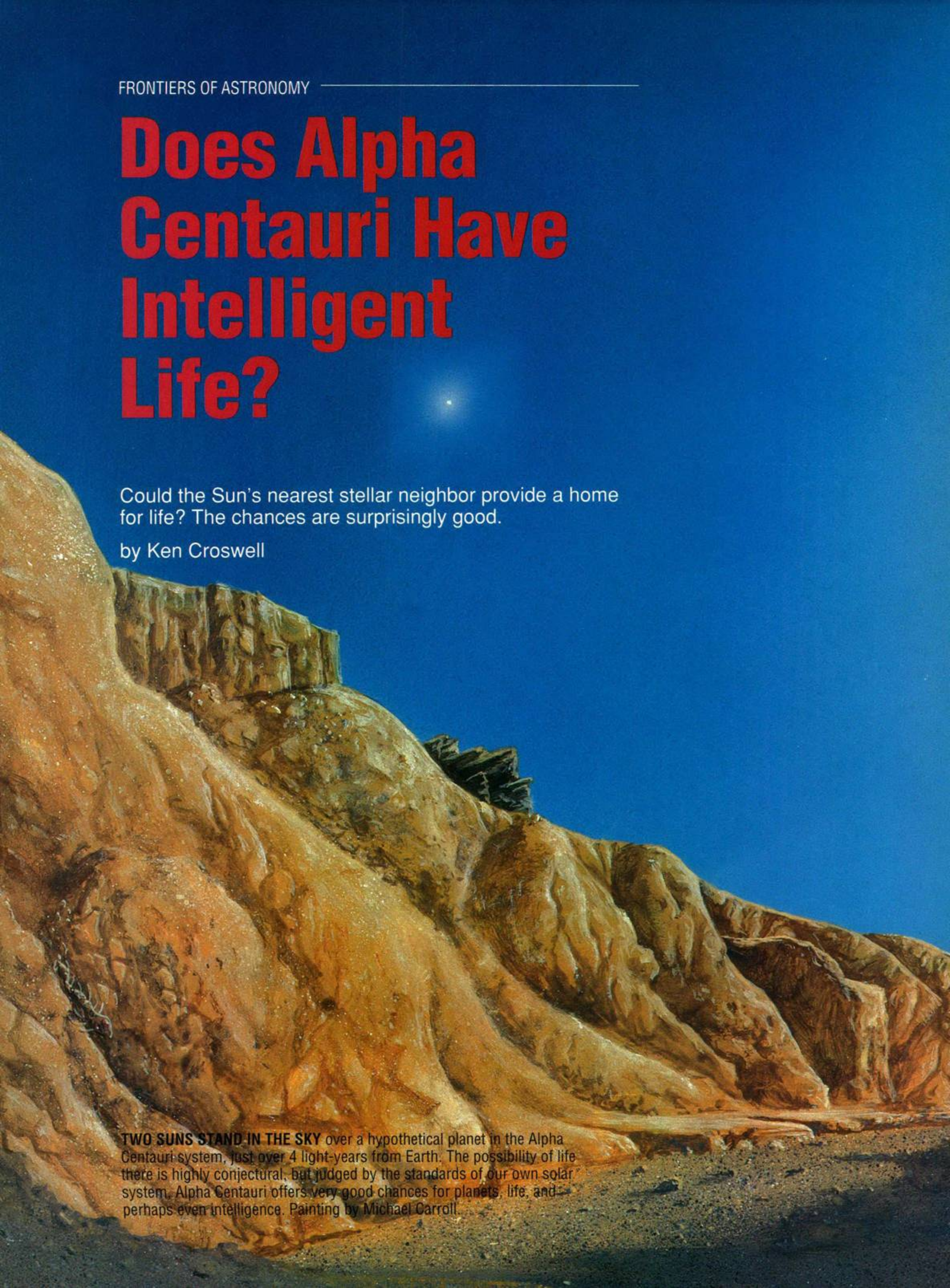
Does Alpha Centauri Have Intelligent Life?

Could the Sun's nearest stellar neighbor provide a home for life? The chances are surprisingly good.

by Ken Croswell



TWO SUNS STAND IN THE SKY over a hypothetical planet in the Alpha Centauri system, just over 4 light-years from Earth. The possibility of life there is highly conjectural, but judged by the standards of our own solar system, Alpha Centauri offers very good chances for planets, life, and perhaps even intelligence. Painting by Michael Carroll.

©
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If astronomers understand how stars work, then the Alpha Centauri system offers two chances for terrestrial-type planet systems.

Alpha Centauri is a special star — not only because it is the closest stellar system to the Sun but also because it is one of the relatively few places in the Milky Way Galaxy that may harbor intelligent life.

Whereas most of the Galaxy's stars are dim red and white dwarfs that could not support life, Alpha Centauri is bright and warm like the Sun and provides abundant energy. Moreover, Alpha Centauri is sufficiently old that any life would have had time to evolve and produce intelligence.

Although we are its closest neighbor, we cannot yet say whether or not life exists around Alpha Centauri. In fact, we don't know if Alpha Centauri even has planets. Despite such uncertainties, we can examine Alpha Centauri to see whether it offers what intelligent life requires. The more we investigate Alpha Centauri, the more promising it looks.

The Layout of Alpha Centauri

The star we call Alpha Centauri is actually a triple system. Its brightest and warmest star is called Alpha Centauri A. It is a yellow star with a spectral type of G2, exactly the same as the Sun's. Therefore its temperature and color also match those of the Sun. Alpha Centauri A is slightly more massive and luminous, however: its mass is 1.09 solar masses and its brightness is 54 percent greater than the Sun's.

Alpha Centauri B, the second brightest star in the system, lies close to A. It is an orange star, cooler and smaller than the Sun. Its spectral type is K1 and its surface temperature is 5300 kelvins, some 500 K lower than the Sun's. The mass of Alpha Centauri B is 0.90 solar masses and the star's brightness is just 44 percent the solar value.

Visible only from latitudes south of about 25° north, the Alpha Centauri system lies 4.35 light-years from the Sun. The two brightest stars orbit each other every 80 years. The mean separation between them is 23 astronomical units — similar to the distance between the Sun and Uranus. (One AU is the distance between the Sun and Earth.) However, the stars' orbit is eccentric, so the separation varies during their 80-year period. When closest, Alpha Centauri A and B lie 11 AU apart — the distance between the Sun and Saturn. When farthest, though, the two stars are 35 AU apart — the separation between the Sun and Neptune.

The third and faintest member of the Alpha Centauri system, Alpha Centauri C, lies a long way from its two brighter companions, in distance and in nature. In fact, Alpha Centauri C lies 13,000 AU from A and B, or 400 times the distance between the Sun and Neptune. This is so great a distance that some astronomers believe the star is not even gravitationally bound to A and B. If Alpha Centauri C *is* attached, however, it must take about a million years to orbit them. So great is the separation that Alpha Centauri C actually lies measurably closer to us than the other two: A and B are 4.35 light-years distant, but Alpha Centauri C is only 4.22 light-years away. Technically speaking, therefore, Alpha Centauri C is the nearest individual star to the Sun. Because of this proximity, astronomers call the star Proxima Centauri.

Proxima is quite far from A and B in other ways as well. Whereas Alpha Centauri A and B are stars like the Sun, Proxima is a dim red dwarf — much fainter, cooler, and smaller than the Sun. Proxima Centauri's spectral type is M5, its temperature is half the Sun's, its mass is one-tenth the Sun's, and its brightness is a mere 0.006 percent that of the Sun. Proxima is so faint that astronomers did not even discover it until 1915.

The Rarity of Alpha Centauri

Alpha Centauri is special because our Sun is special. The Sun emits lots of energy, just what life needs. But contrary to what many astronomy textbooks say, the Sun is *not* an average star. It is far above average in luminosity, mass, and size. If it weren't, we wouldn't be here.

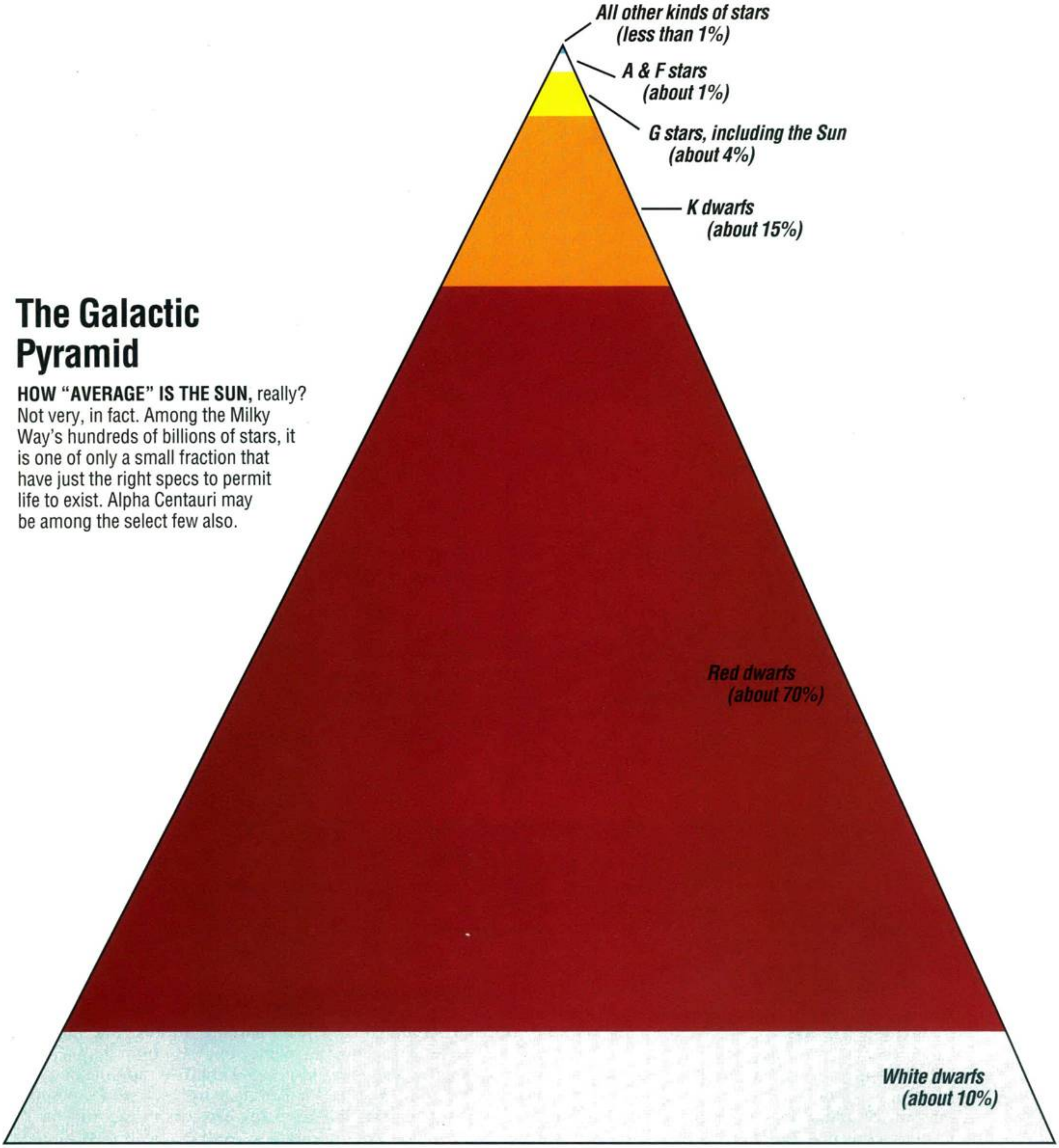
We cannot appreciate either Alpha Centauri or the Sun until we look at the Galaxy's other stars. Most are incapable of sustaining life. Seventy percent of all stars in the Galaxy are red dwarfs like Proxima Centauri, too faint, too cool, and in some cases too variable to support life. About 15 percent are orange K-type dwarfs. Although the more luminous K dwarfs (like Alpha Centauri B) may be bright and warm enough for life, the fainter ones in the class may be too dim and cool. Another 10 percent of stars are white dwarfs — dying stars that either could not have life or must have destroyed any life they once had.

That leaves the brightest 5 percent of all stars in the Galaxy, a privileged group to which both the Sun and Alpha Centauri A belong. Most of this upper 5 percent consists of yellow G-type stars that are bright, warm, and good for life.

Because they power any life around them, the stars in a stellar system are the first things to consider for intelligent life. A star must pass five different tests before we can call it a promising place for life. Passing all five tests is not easy. Most stars in the Galaxy

The Galactic Pyramid

HOW "AVERAGE" IS THE SUN, really? Not very, in fact. Among the Milky Way's hundreds of billions of stars, it is one of only a small fraction that have just the right specs to permit life to exist. Alpha Centauri may be among the select few also.



would fail. In the case of Alpha Centauri, however, we will see that Alpha Centauri A passes all five tests, Alpha Centauri B passes either all or all but one, and only Proxima Centauri flunks out.

Good Stars

The first test is the easiest. To ensure a star's maturity and stability, it has to be on the main sequence. Main-sequence stars fuse hydrogen into helium at their cores, generating light and heat. Because hydrogen is so abundant in stars, most of them stay on the main sequence a long time, giving life a chance to develop.

After a star exhausts the hydrogen at its core, the star goes through rapid changes, first becoming a red giant and then a white dwarf. These changes are fun for astronomers to study but highly detrimental to any life orbiting the star! Ninety percent of the Galaxy's stars are on the main sequence, so most, including

The Sun and Its Nearest Neighbors

	Sun	Alpha Cen A	Alpha Cen B	Proxima
Color	Yellow	Yellow	Orange	Red
Spectral type	G2	G2	K1	M5
Temperature	5800 K	5800 K	5300 K	2700 K
Mass	1.00	1.09	0.90	0.1
Radius	1.00	1.2	0.8	0.2
Brightness	1.00	1.54	0.44	0.00006
Apparent magnitude	–26.7	0.0	1.4	11.1
Absolute magnitude	4.85	4.38	5.74	15.54
Distance (light-years)	0.00	4.35	4.35	4.22

the Sun and all three components of Alpha Centauri, pass this test.

The second test is much tougher, however, and most stars in the Galaxy fail it. We want the star to have the right spectral type, because this determines how much energy a star emits. On the main sequence, the "earlier" the spectral type — that is, the hotter and bluer the star — the more energy it puts out.

Although they might at first seem the best, the hottest stars — those with spectral types O, B, A, and early F — are actually the worst. These stars are so bright they burn their fuel fast and die quickly. A typical O star like Iota Orionis has a lifetime of just 10 million years. A typical B star like Regulus lives just 100 million years. And a typical A star like Sirius lives only a billion years or so. On Earth, intelligence took 4.6 billion years to develop. If we are typical, then O, B, A, and early F stars can't have intelligent life because they burn out before it establishes itself.

The opposite end of the main sequence is just as bad, but in a different way. M-type main-sequence stars (red dwarfs such as Proxima Centauri) indeed live for tens or hundreds of billions of years. But they emit little energy during their long lives. Red dwarfs therefore do not give off enough energy to support life.

Between the stars that are too hot and those that are too cool, we find the stars that are just right. As our existence proves, yellow G-type stars like the Sun can give rise not only to life but to intelligent life. What about other spectral types? Late (cool) F stars may be fine, too — they produce even more energy than the Sun, and they probably live long enough to foster intelligence. More problematic are the orange K stars, cooler than the Sun. Do they produce enough energy? The brighter and hotter ones — K0, K1, and K2 stars — may, but the fainter and cooler K stars (later than K5) may not.

How does Alpha Centauri fare in this second test? With a G2 spectral type identical to the Sun's, Alpha Centauri A passes easily. Alpha Centauri B is a K1 star, so it is brighter and hotter than most K stars and therefore may pass this test or it may not. And, of course, the red dwarf Proxima Centauri is a hopeless case.

For our third test, a star must demonstrate that it is stable. We do not want the star's brightness to vary so much that the star would alternately freeze and fry any life that does manage to develop around it. Like the Sun, Alpha Centauri A and B are stable and do not vary in brightness.

But because Alpha Centauri A and B form a binary pair there's a further issue. How much does the light received by the planets of one star vary as the other star revolves around it? During their 80-year orbit, the separation between A and B changes from 11 AU to 35 AU. As viewed from the planets of Alpha Centauri A, the brightness of Alpha Centauri B increases as B approaches A and then decreases as B recedes from A. Likewise, as viewed from the planets of Alpha Centauri B, the brightness of Alpha Centauri A increases and decreases as the star approaches and recedes.

Fortunately, the variation is too small to matter. As viewed from a planet orbiting A, Alpha Centauri B ranges from apparent magnitude –18.1 at faintest to –20.6 at brightest. (The Full Moon shines at –12.7 magnitude and the Sun –26.7.) But even when B is brightest, Alpha Centauri A (viewed from one AU) is over 400 times brighter. B's variation therefore means nothing since the light received on Alpha Centauri A's planet comes almost entirely from its own star.

Reversing the scenario brings us to the same conclusion. When nearest B, Alpha Centauri A shines at magnitude –21.9 as viewed from the planets of Alpha Centauri B. When farthest, Alpha Centauri A drops to magnitude –19.4. But again, the light that B's planets receive is dominated by light from B, not A, so the variation isn't harmful. In this case, the total light received by a planet one AU from Alpha Centauri B varies by just 3 percent as A approaches and recedes. This is smaller than the variation we suffer each year as the Earth revolves about the Sun on its slightly eccentric orbit. So both A and B pass the test for stability.

But poor Proxima. It flunked our last test and it fails this, too. Like many red dwarfs, Proxima Centauri is a flare star, prone to outbursts that cause its light to double or triple in just a few minutes. Any life around Proxima would have to be quite hardy to survive such outbursts.

The fourth test concerns the stars' ages. The Sun is about 4.6 billion years old, so on Earth intelligent life took that long to evolve. This is a lengthy time and

The Local Top Ten Stars (of the Nearest 100)

Rank	Star	Absolute Magnitude	Spectral type	Distance (l-y)
1	Sirius A	1.42	A1	8.7
2	Altair	2.24	A7	16.5
3	Procyon A	2.64	F5	11.4
4	**Alpha Centauri A**	**4.38**	**G2**	**4.35**
5	Eta Cassiopeiae A	4.61	G0	19.1
6	Delta Pavonis	4.76	G7	18.6
7	**Sun**	**4.85**	**G2**	**0.0**
8	Tau Ceti	5.72	G8	11.8
9	**Alpha Centauri B**	**5.74**	**K1**	**4.35**
10	70 Ophiuchi A	5.76	K0	16.1

roughly half the stars in the Galaxy are younger than the Sun. If intelligence takes 4 to 5 billion years to develop, these young stars cannot have intelligent life around them yet. In assessing a star's chances for intelligent life, we therefore want the star to be at least as old as the Sun. For most stars, however, determining age is tough work. We know the Sun's age only because we can date rocks on the Earth and Moon.

Remarkably, though, we can also date Alpha Centauri. A main-sequence star slowly brightens as it ages. For example, the Sun is now about 40 percent brighter than it was at birth. If we know a star's mass precisely, we can calculate how the star's luminosity varies as the star ages. Alpha Centauri A and B form a binary, so we can determine their masses quite accurately. Because they are so close to us, we also know their distances and luminosities precisely. We can therefore determine how old these stars — with masses of 1.09 and 0.90 Suns — must be to be as bright as they now are. Brian Flannery of Exxon Corporation and Thomas Ayres of the University of Colorado did this in 1978 and found that Alpha Centauri A and B are both about 6 billion years old. In 1986, Pierre Demarque, D. B. Guenther, and William van Altena of Yale University used more recent data to find that both stars are about 5 billion years old. Alpha Centauri A and B are therefore a bit older than the Sun, so intelligence has had time to evolve around them.

What about Proxima? If Proxima was born with A and B, then it too must be 5 or 6 billion years old. However, the star's flare activity suggests instead it is young, since flare activity is a sign of youth. Proxima Centauri may be only a billion years old, which means it did not form with A and B but was captured by them. If Proxima really is only a billion or so years old, then it fails this test too.

Our fifth and final test: Do the stars have the heavy elements — such as carbon, nitrogen, oxygen, and iron — that life needs? Like most stars, the Sun is primarily hydrogen and helium, but 2 percent of the Sun's weight is in metals. (Astronomers call all elements heavier than helium "metals.") Although 2 percent may not sound like a lot, this enrichment of the material the Sun and planets formed from was enough to give rise to us. Furthermore, the Sun is metal-rich compared with many other stars in the Galaxy. In particular, older stars tend to have fewer metals. Since Alpha Centauri A and B are older than the Sun, we might worry that these stars do not have enough metals to develop life.

Fortunately, Alpha Centauri A and B are both metal-rich stars. Astronomers have measured the metal abundance of the two main stars in Alpha Centauri and they find that it has even more metals than the Sun does. Thus Alpha Centauri passes this test, too.

How did the three stars do in these tests? Alpha Centauri A passed all of them quite well. It is a stable, metal-rich, main-sequence G star with a slightly greater age than the Sun. Alpha Centauri B passed at least four of the five tests. It, too, is a stable, metal-rich, main-sequence star that is old enough for intelligent life. The only possible problem is its K spectral type, which indicates the star may be too faint and cool to support life. Finally, the red dwarf Proxima Centauri didn't do well at all.

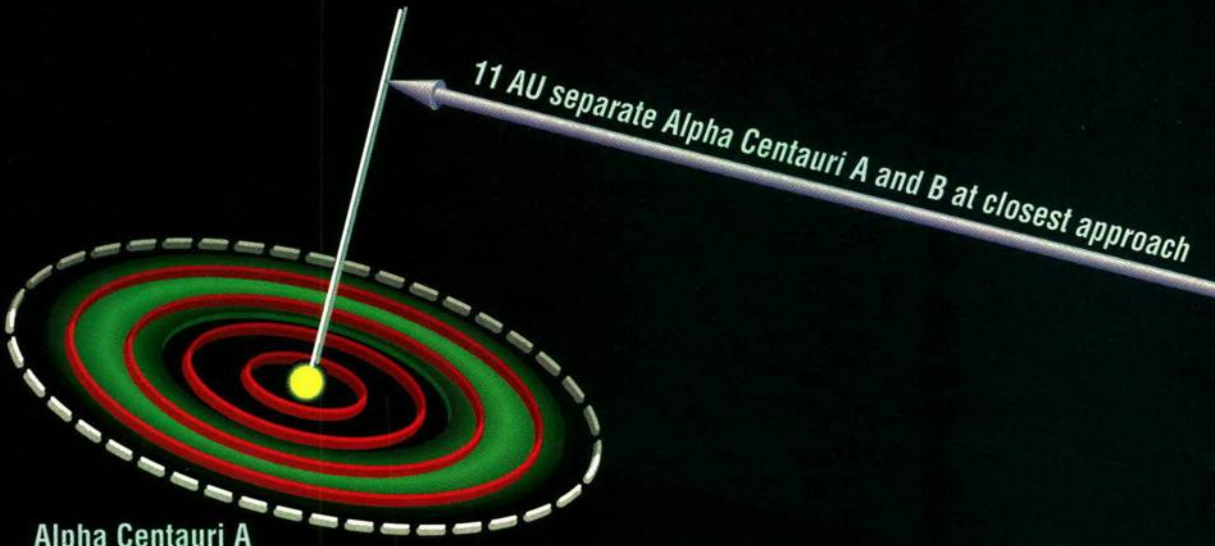
Good Planets?

Vital as it is for life, a good star is not enough. We also need a good planet to orbit the good star — a warm, rocky planet like Earth, full of liquid water.

Unfortunately, it is here that big uncertainties arise. We don't know whether Alpha Centauri even *has* planets, much less whether they would be good places for life. Another problem is that because Alpha Centauri A and B lie close to each other, one star's gravity may disturb the planets orbiting the other star.

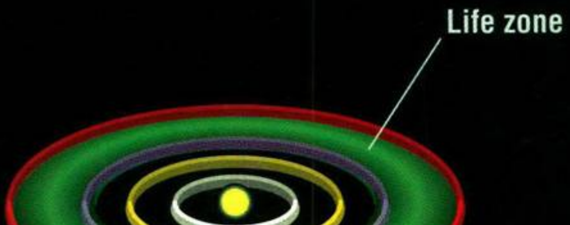
If Alpha Centauri A and B were very close together, then planets could revolve at a distance around both stars. Inhabitants of such a solar system would always see a double sun in their daytime sky. On the other hand, if the two stars were very far apart, then each star could have its own planetary system. Inhabitants would call one star their sun and see the other as a very bright point of light in the sky. Unfortunately, Alpha Centauri A and B fall between these two extremes, which poses problems for planets. (Since it is so far from its partners, Proxima Centauri can and

Possible planets at Alpha Centauri


11 AU separate Alpha Centauri A and B at closest approach

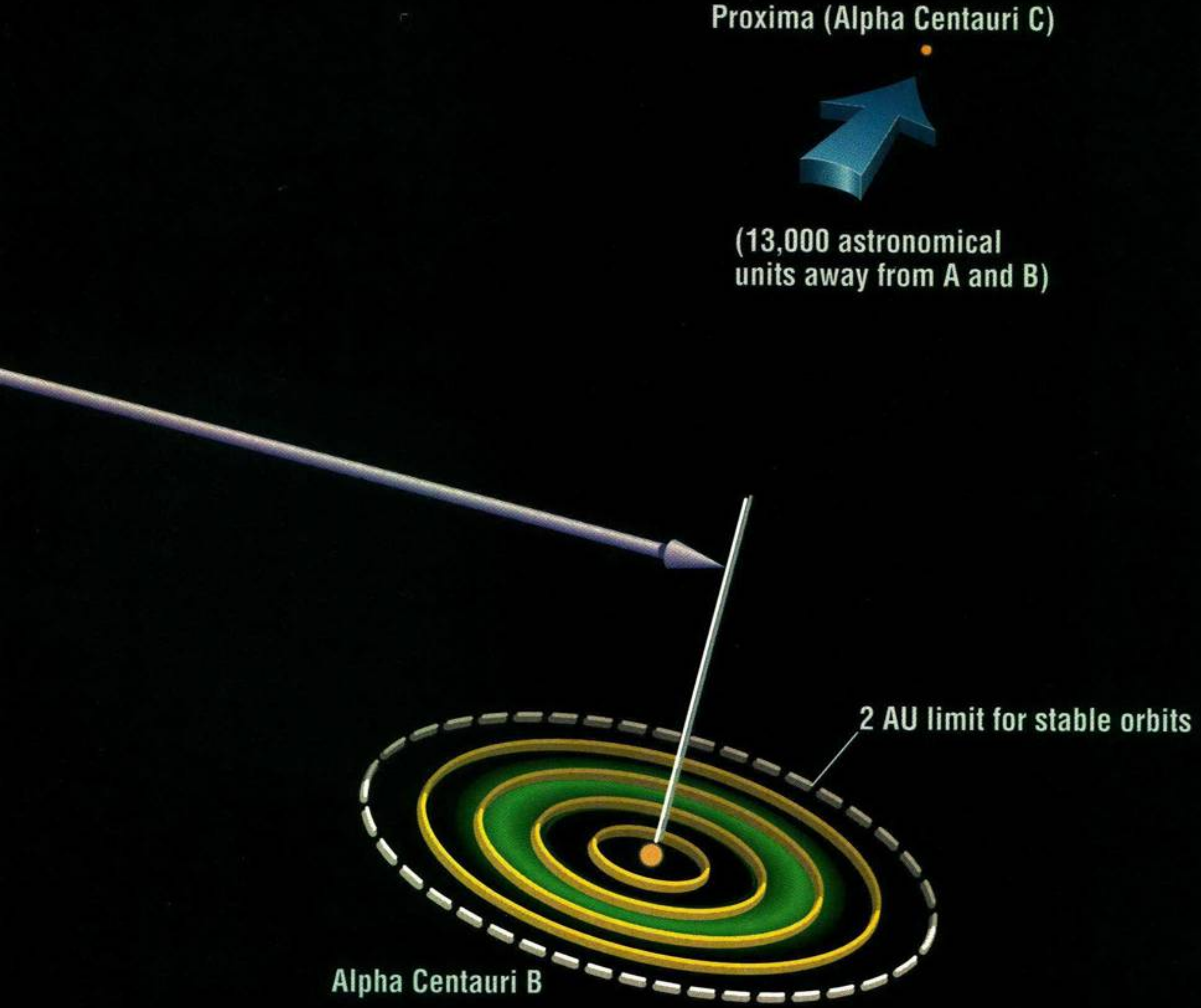
Alpha Centauri A

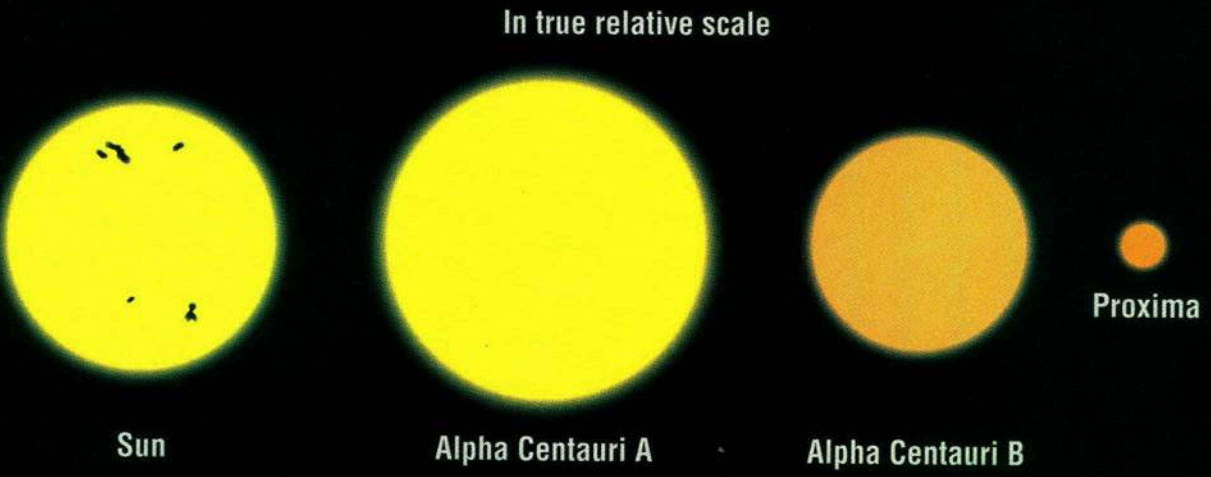
IF ALPHA CENTAURI A AND B HAVE PLANETS spaced apart like Mercury, Venus, Earth, and Mars, the chances are good that at least one of them will fall into the star's life zone (green band) the bright, warm region where water could remain liquid.



The Sun and its terrestrial planets
(on the same scale)

ART by *Steven G. Davis*


Proxima (Alpha Centauri C)
(13,000 astronomical units away from A and B)
2 AU limit for stable orbits
Alpha Centauri B


In true relative scale
Sun
Alpha Centauri A
Alpha Centauri B
Proxima

Ten Questions for Any Star

	Sun	Alpha Cen A	Alpha Cen B	Proxima A
On the main sequence?	Yes	Yes	Yes	Yes
Of the right spectral type?	Yes	Yes	Maybe	No
Constant in brightness?	Yes	Yes	Yes	No
Old enough?	Yes	Yes	Yes	No?
Rich in metals?	Yes	Yes	Yes	?
Has stable planetary orbits?	Yes	Yes	Yes	Yes
Could planets form?	Yes	?	?	Yes
Do planets actually exist?	Yes	?	?	?
Small, rocky planets possible?	Yes	Yes	Yes	Yes?
Planets in the life zone?	Yes	Maybe	Maybe	No

probably does have planets, but since Proxima is a red dwarf, the planets must be lifeless.)

Nonetheless, we can proceed as before by submitting the system to different tests. The first test: Do stable orbits exist? If we put a planet in orbit 1 AU from Alpha Centauri A, would it stay there? Or would the gravity of Alpha Centauri B rip it away? Celestial mechanics shows that stable orbits definitely exist around either star — provided the planets lie no farther from their star than one-fifth the closest distance the two stars ever get to each other. Since A and B get as close as 11 AU, this means that each star could have planets with stable orbits out to a distance of at least 2 AU.

In our solar system, four planets lie within 2 AU of the Sun: Mercury (0.4 AU from the Sun), Venus (0.7 AU), Earth (1.0 AU), and Mars (1.5 AU). Therefore, Alpha Centauri A and B could each have four planets with orbits just like those of the inner solar system.

The second test is tougher. Even though planets can exist around Alpha Centauri A and B, could such planets have formed in the first place? In the solar system, Jupiter's mighty gravity disturbed the developing solar system and prevented a planet from forming between it and Mars. That is why our solar system has an asteroid belt between Mars and Jupiter. The situation around Alpha Centauri could be far worse, for both Alpha Centauri A and B are about a thousand times more massive than Jupiter. When the protoplanetary material around Alpha Centauri A and B was attempting to form planets, the gravity of one star may have so thoroughly disturbed the developing planets of the other that no planets formed around either. As a consequence, all that may exist around Alpha Centauri A and B are multitudes of asteroids.

The ultimate question, though, is not whether planets have stable orbits or whether they could have formed, but whether they exist *today*. We have no evidence for any, of course, but some astronomers hope that when the *Hubble Space Telescope* is repaired it may spot planets around Alpha Centauri. Until then, we simply do not know if Alpha Centauri has any planets. We can nevertheless proceed by supposing each star does have four planets with orbits similar to those of Mercury, Venus, Earth, and Mars. The next question: Are these planets good or bad? "Good planets" are small, rocky worlds where life could form if the planets are the right distance from their star. "Bad planets" are huge gas-balls with lots of hydrogen and helium, probably incapable of forming advanced life even if they orbit close to their star. In our solar system, the good planets — Mercury, Venus, Earth, and Mars — lie in the inner solar system, whereas the bad planets — Jupiter, Saturn, Uranus, and Neptune — lie in the outer solar system.

Astronomers believe other solar systems may follow the same pattern: the inner planets small and rocky, the outer planets large and gaseous. Our planets condensed at different places and therefore at different temperatures in the primordial solar nebula. In the inner solar system (which was hot), only hardy substances like rock and iron could condense, which is why the four inner planets consist of rock and iron. In the outer solar system, however, the pervasive cold allowed substances other than rock and iron to survive, such as methane and ammonia. These planets grew huge and became the gas giants.

What do we expect around Alpha Centauri A and B? Any planets within two AU of either star must have formed from a hot nebula. These worlds, if they exist, are almost certainly small, rocky planets like Earth rather than lifeless gas giants like Jupiter. Thus even though both stars can have only truncated solar systems, any planets that did arise are just the sort we're looking for.

The final question we ask is whether any of the planets around A or B lie at the right distance from their star. In our solar system, Venus is too close to the Sun and is too hot, while Mars is too far and too cold. Only Earth is the right temperature, for only Earth lies at the right distance from the Sun.

The region in our solar system where temperatures are just right is called the life zone. Unfortunately, different astronomers reach different conclusions concerning how wide the Sun's life zone is. One estimate made many years ago says it extends from only 0.95 to 1.01 AU. A more recent estimate, however, says it extends from 0.95 to 1.5 AU. Of course, it is more than just a planet's distance that determines temperature. In general, the bigger a planet, the warmer it will be. In

Life at Alpha Centauri? The hardest questions to answer aren't astronomical — the real stumpers are the biological ones.

our solar system, Mars is small and cold, but some astronomers believe that if Mars were the size of Earth, it might be warm enough for life.

What is the chance that Alpha Centauri A or B has a planet in its life zone? In our system, inner planets are spaced about 0.4 AU apart. Suppose the planets of Alpha Centauri A and B are also spaced 0.4 AU apart. If the life zone of each star is 0.1 AU wide, then each star has a one in four chance of having a planet in its life zone. If the life zone is wider, the probability grows. For example, if the life zone is really 0.2 AU wide, then each star has a 50-50 chance of putting a planet into its life zone. Such a planet could be a warm, watery world like Earth and an excellent place for breeding life.

It's frustrating, but we can't reach any firm conclusions about Alpha Centauri. Whereas we could say with certainty that at least one of its stars is ideal, we can say little about any planets there. On the positive side, Earth-like planets can have stable, Earth-like orbits around either A or B. On the negative, such planets might never have formed in the first place and we have no evidence that planets of any kind exist around Alpha Centauri.

Does Alpha Centauri Have Intelligent Life?

But if Earth-like planets exist, did life actually develop on them? And is some of that life intelligent? Unfortunately, the answers depend not on astronomy but on biology. In confronting astronomical issues, we could often answer the questions we posed. The same is not true for the biological issues. In fact, we have no good answers *whatsoever* when we begin to ask biological questions. Yet the question of intelligent life around Alpha Centauri may hinge more on biological factors than on astronomical ones.

There are three chief biological questions. The first: Given a warm, watery planet like Earth governed by a bright, warm star like the Sun, will primitive life develop? Scientists sometimes assume it will since that is what happened on Earth. But we have no assurance that Earth is typical, for it is the only planet on which we have ever detected life. Furthermore, the origin of life even here on Earth remains a mystery. Thus even if Alpha Centauri has warm, watery planets, these worlds could be completely lifeless.

Second, if primitive life does manage to develop, will that life evolve into more advanced forms? On Earth it obviously did. Single-celled organisms became multi-celled, which then evolved into more complex life forms such as plants and animals. But we have no guarantee that the same process will occur on other worlds. Even if Alpha Centauri has warm, watery planets bearing life, it's possible the life there consists of nothing more than primitive single-celled organisms.

Finally, if advanced life does develop, will intelligent life evolve with it? Again, no guarantees. On other planets, strength and speed may count for more than intelligence. Even if a species like us managed to arise on such a planet, we might soon be killed off by stronger, faster, dumber competitors. Thus Alpha Centauri could have planets with advanced life that lacks intelligence. The dominant species might be a plant or a tree.

The Promise of Alpha Centauri

The three biological questions are not unique to Alpha Centauri. They confront us whenever we examine any star system for intelligent life. That we cannot answer them should not detract from the great promise that Alpha Centauri holds for harboring intelligent life.

Alpha Centauri A is one of the best stars we could ask for — it resembles the Sun more than any of the 70 nearest stars do. With a spectral type of G2, a high metal abundance, and an age exceeding the Sun's, the star could easily support intelligent life on its planets, if such exist. And Alpha Centauri B, though fainter and cooler than the Sun, also offers hope that life has established itself on planets orbiting it.

Furthermore, these very promising stars are not just any stars in the Galaxy. They are the stars closest to the Sun. The next nearest star to us beyond Alpha Centauri is Barnard's star, a worthless red dwarf like Proxima. The next closest G-type star beyond Alpha Centauri is Tau Ceti, twice as distant as Barnard's star. Though it is a single star that may have planets, Tau Ceti has only about a third the Sun's abundance of the heavy elements such as carbon and oxygen that life needs.

Alpha Centauri is therefore very special — special not only for its proximity but also for its promise. If Alpha Centauri has planets, it is even more special since one or more of those planets could resemble Earth. And if we ever launch missions to other stars in the Galaxy, Alpha Centauri will certainly be our first target. ☐

Ken Croswell received his doctorate in astronomy from Harvard University and has written for New Scientist, Star Date, *and Time-Life Books. His last article for ASTRONOMY was "A Star That Breaks All the Rules" in the January 1991 issue.*

Rendezvous with Venus

Late last year scientists saw the results from *Galileo*'s first planetary encounter of its 6-year journey — a flyby of Venus.

by Alan Dyer

Galileo is taking the scenic route to Jupiter. Although it was launched in 1989, the probe won't reach its destination until December 1995. Along the way, *Galileo*'s circuitous path takes it past Venus, Earth (twice), and two asteroids. On February 10, 1990, *Galileo* reached its first waystation, coming within 10,000 miles of the cloudtops of Venus.

The purpose of the Venus flyby was to steal some velocity from Venus. *Galileo* needed the boost in speed to help it get out to distant Jupiter. However, having a space probe bristling with instruments fly past a planet, even one as well-explored as Venus, is a scientific opportunity not to be missed.

Although *Galileo* made its Venus observations in February 1990, they were not relayed to Earth until the third week of November. The delay was purely technical. While flying through the inner solar system, *Galileo*'s umbrella-like dish antenna has remained folded and shaded to prevent it from overheating in the Sun's heat. Without the aid of the powerful antenna, *Galileo* could not transmit the reams of data across space from Venus to Earth. Instead, the Venus science was stored on board *Galileo* as one very valuable tape recorder load. When *Galileo* approached Earth in late 1990, technicians used *Galileo*'s low-gain antenna to transmit the stored pictures and sensor readings to waiting scientists.

New Wavelengths, New Resolutions

Earlier probes specifically designed for Venus, such as *Mariner 10, Pioneer Venus Orbiter,* and the Soviet series of *Venera* probes, had revealed the now-familiar picture of Venus — a planet with oven-like surface temperatures wrapped in sulfuric acid clouds. Venus is a decidedly unpleasant place.

But despite the spate of Venus probes over the last few years, including the current *Magellan* radar mapper, astronomers have remained puzzled by a number of questions. For one thing, the planet itself only rotates once every 243 days, yet Venus' clouds whip around the planet once every 4 days. What drives this super-rotating atmosphere? What kind of weather does Venus have? Are there thunderstorms? As it turned out, the instruments on board *Galileo* , while designed for Jupiter, were ideal for answering some of these questions.

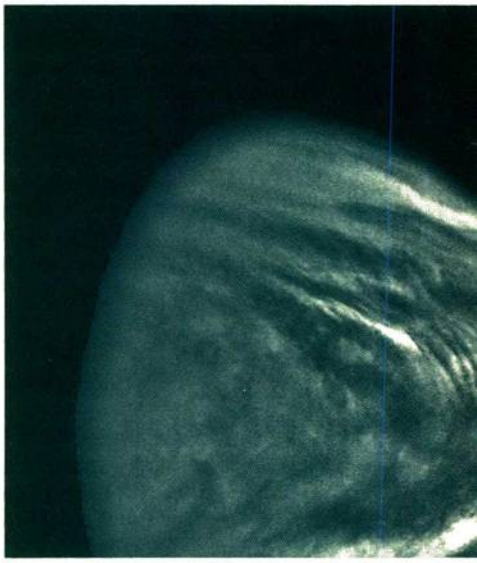
The *Galileo* instrument that returns photographs is officially known as the Solid State Imager, or SSI. This camera's high resolution allowed scientists to look for small short-lived cloud features on Venus, something not possible with earlier probes.

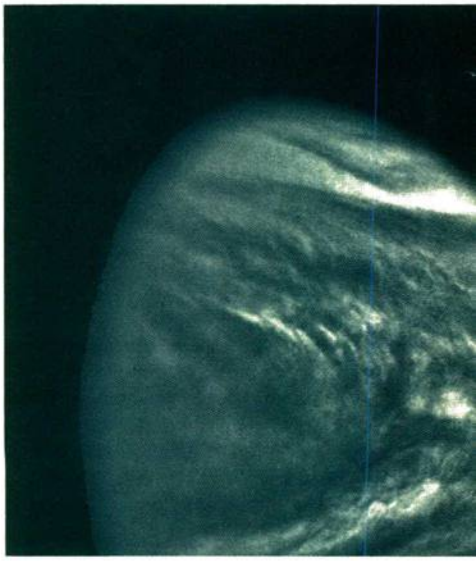
On Venus the clouds are everywhere, with not a clear spot in sight. The clouds seen by *Galileo's* SSI camera are floating in the uppermost layers of the atmosphere, about 40 miles above the surface of Venus. Initial results from *Galileo* have confirmed that the upper clouds move east to west, carried by winds that blow at over 200 miles per hour. Within this overall flow *Galileo* found considerable small-scale activity, particularly convective cells boiling up near the equator on the afternoon side of Venus, just as thunderstorms and cumulus clouds do on Earth.

Galileo scientists also used the SSI camera to search for lightning on Venus but found none in their first look at the data. However, considering the lightning search was limited to a few hours, the negative results weren't surprising.

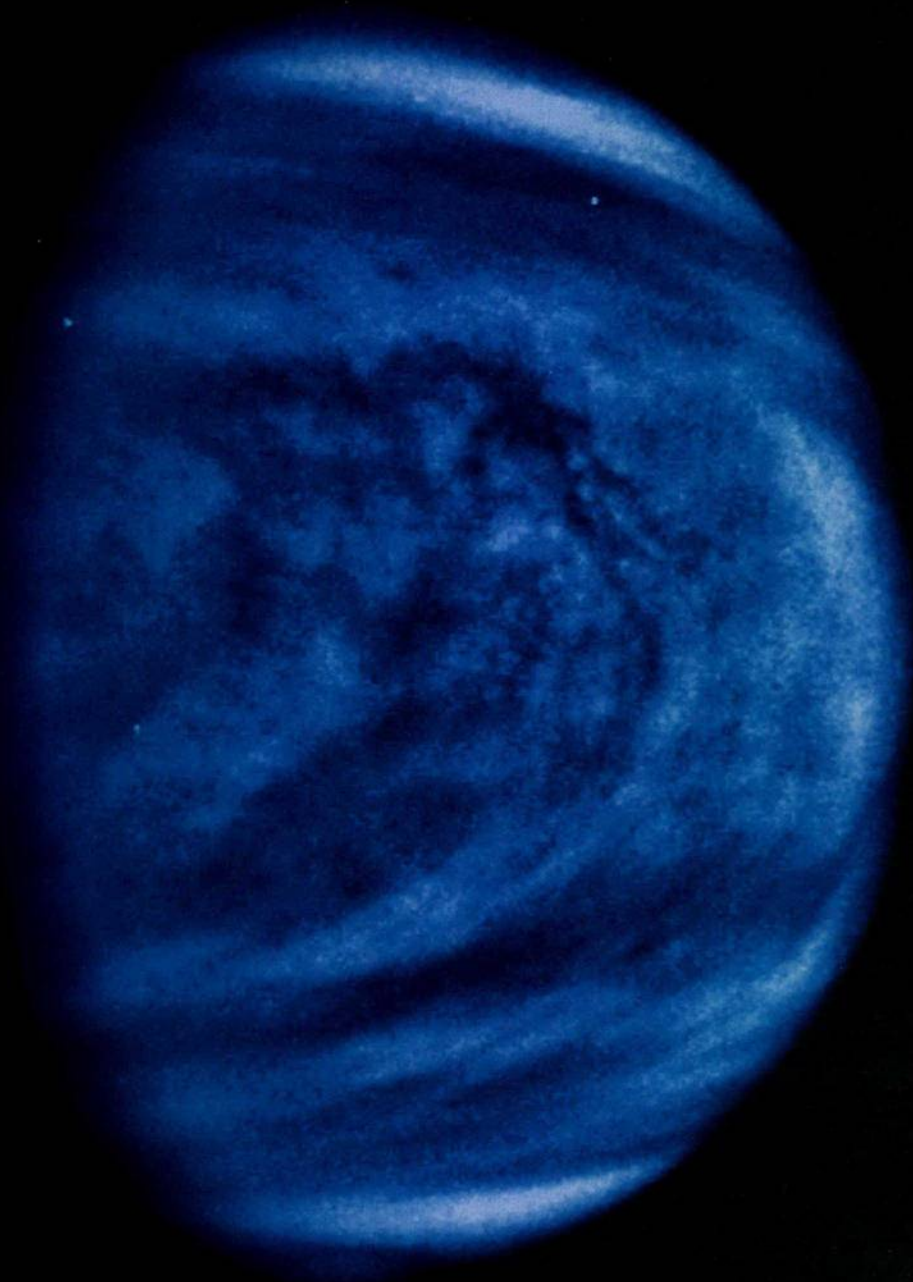
Finding the Hot Spots

Astronomers were particularly interested in scanning Venus with a

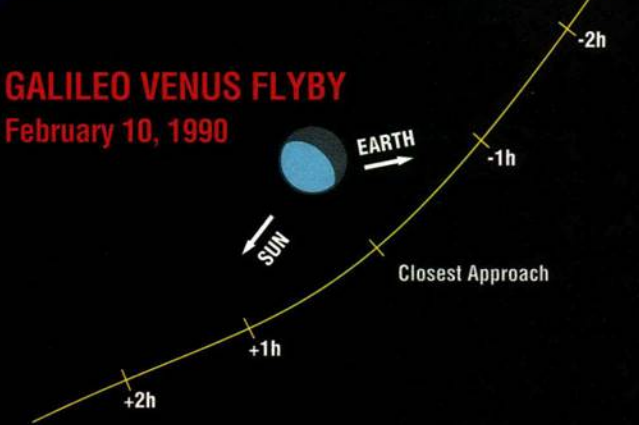




THE SWIRLING CLOUDS of Venus were captured in a series of time-lapse images. The bottom image was taken 6 hours later than the top one and shows the right-to-left or westward motion of the clouds. NASA photos.



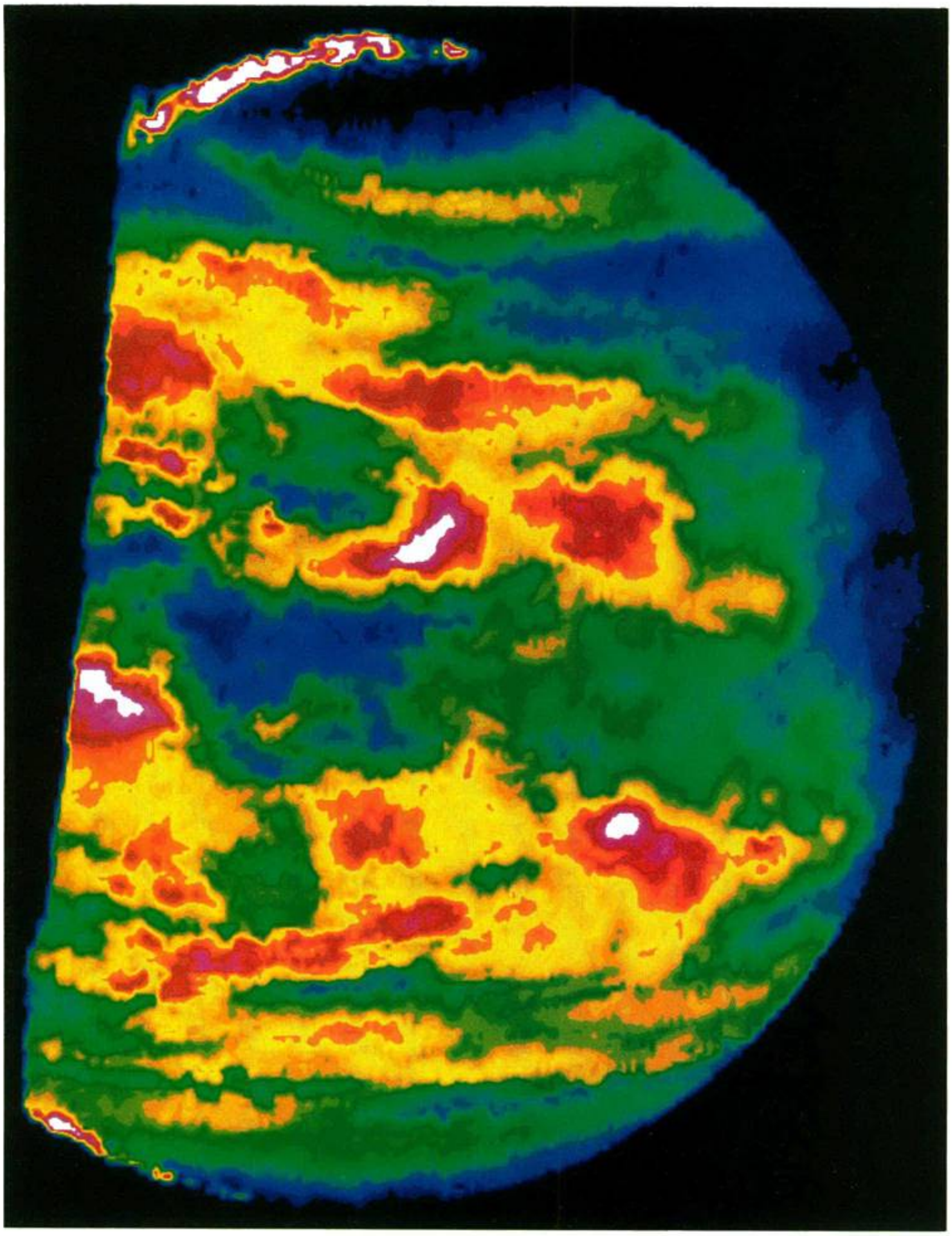
AS GALILEO DEPARTED it snapped this image of the day side of Venus from a distance of 1.7 million miles. The image has been processed to emphasize small cloud features. NASA photo.



GALILEO VENUS FLYBY

February 10, 1990

GALILEO SAW THE NIGHT SIDE of Venus as it approached. It then crossed over the sunrise terminator and looked back at the day side as it flew away.



***GALILEO*'S INFRARED EYES,** left, revealed holes in the middle cloud deck (the white and red areas) where heat from below penetrates through the cooler clouds. A close-up image, above, spans 40° in latitude and shows mid-level cloud features as small as 13 miles across. NASA photos.

device on *Galileo* called NIMS — the Near Infrared Mapping Spectrometer. NIMS is sensitive to the band of wavelengths from just below visible red light to the realm of heat radiation. At these long wavelengths, the clouds of Venus are translucent, a fact discovered by astronomer David Allen from ground-based observations in 1983. This translucency allows astronomers to peer through the otherwise opaque upper cloud deck for an unprecedented view of cloud structures deep in a middle layer of the atmosphere.

The amount of detail that NIMS revealed delighted astronomers. As NIMS team member Kevin Baines told ASTRONOMY, "The blandest planet in the solar system in visible light showed incredible structure in the infrared."

When on the day side of Venus, NIMS was partly blinded by the planet's brilliance. NIMS really came into its own on the night side of Venus where, like a nightvision camera, it could create an image of Venus using only the heat radiated through the clouds. The NIMS global heat map showed a wealth of hot and cool spots in the atmosphere. The hottest areas were thin patches in the otherwise dense cloud deck enshrouding the planet some 30 miles above the surface.

NIMS also discovered thunderstorm-like cloud cells in the middle layers of the atmosphere. These storms well up at the equator then migrate poleward. At a latitude of about 45° north and south, the cells become sheered into long streaky clouds by the high speed east-to-west winds.

Beneath the Clouds

Below the lowest layer of clouds and haze, from an altitude of 18 miles on down, astronomers think the atmosphere of Venus is relatively cloud-free. Astronomers at first hoped that NIMS would be able to see right down to the surface to look for hot spots from active volcanoes. So far the search has drawn a blank.

Eventually, once *Magellan* completes its radar mapping, scientists will be able to compare *Galileo's* thermal maps of the atmosphere to surface maps of Venus from the *Magellan* orbiter. They'll look for correlations between hot spots in the atmosphere and features on the surface.

The complete picture of Venus' weather patterns will come from combining the visible and ultraviolet light images taken with the SSI camera with the infrared results from NIMS. "For the first time we hope to be able to put together a three-dimensional view of the atmosphere of Venus, one that spans latitude, longitude, and altitude," said Baines. That in turn should help solve the puzzle of what drives the Venusian clouds into their frenzied high-speed rotation around the planet.

But for the moment, the most immediate result from *Galileo* is that the dress rehearsal at Venus has proven *Galileo* to be a powerful discovery machine. Scientists can't wait until it gets to Jupiter. ☐

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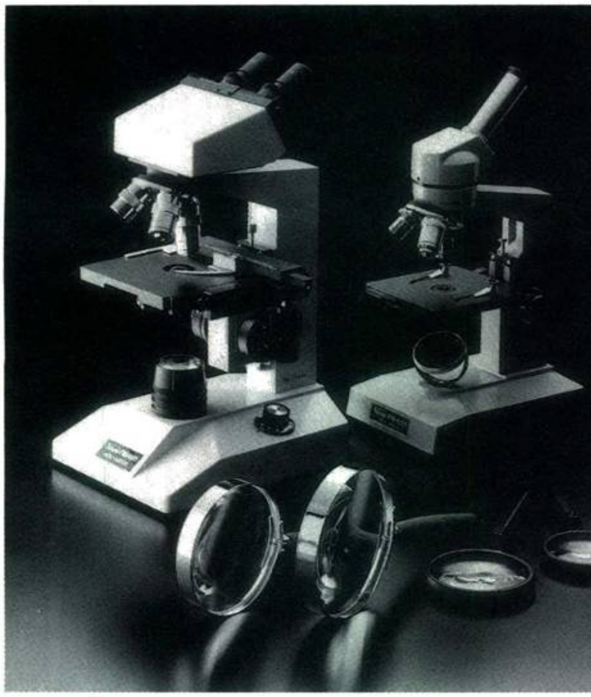

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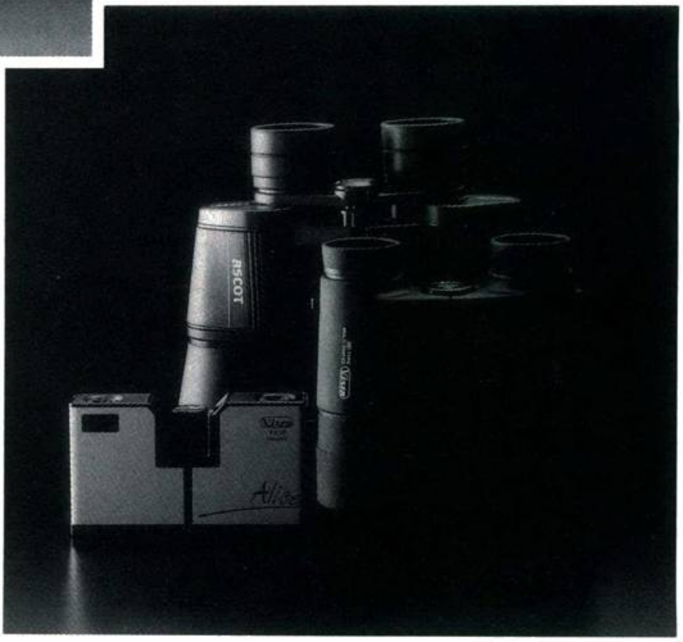

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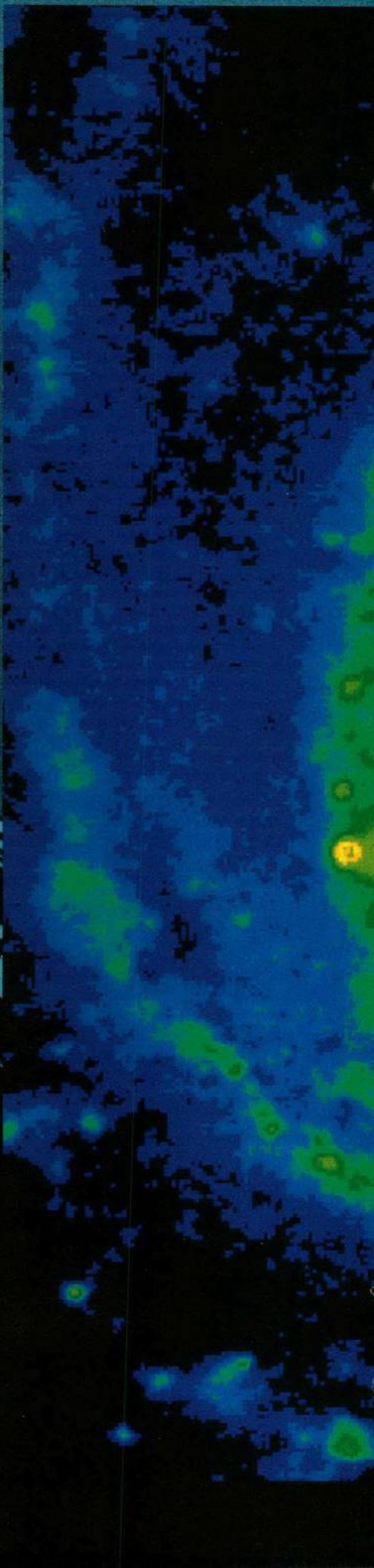
Keck's First Light

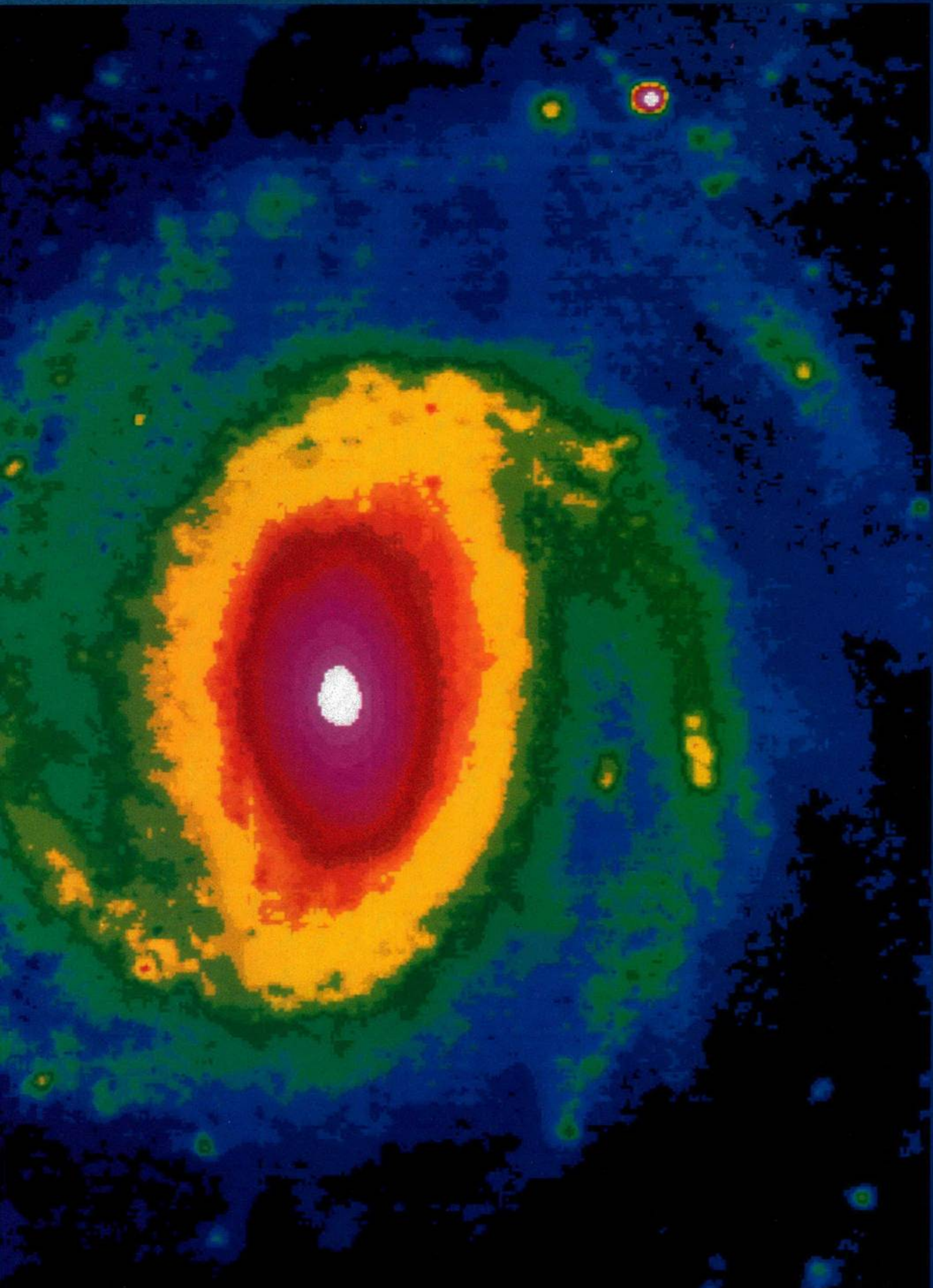
Although not yet complete, the world's largest telescope has produced an historic first-light image.

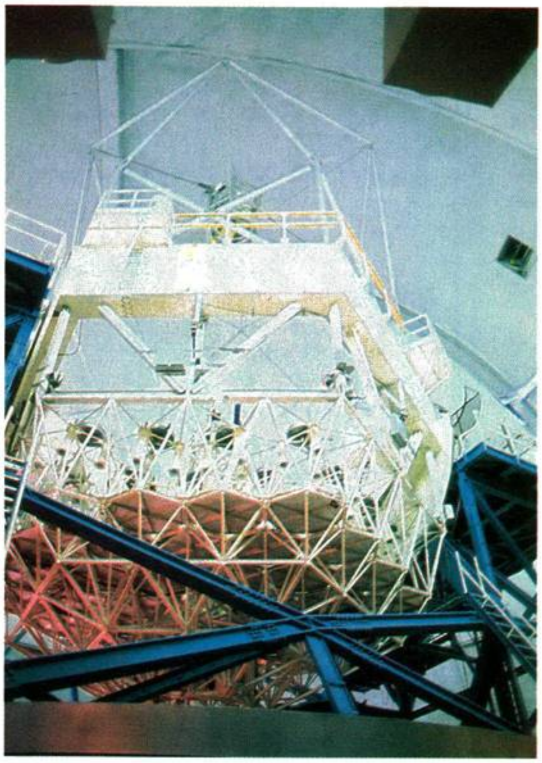
by David J. Eicher



“We’ve reached a very significant milestone in the completion of the telescope,” says Gerald M. Smith, project manager for the Keck telescope and a staffer for the California Association for Research in Astronomy (CARA). CARA was formed in 1985 to manage the construction and operation of what will be the world's largest telescope when it is completed in late 1991. Five years after beginning the project, CARA and its scientists and engineers have plenty to celebrate. In an era of uncertain performance and sophisticated, sometimes unpredictable equipment, CARA's Keck project is soaring ahead perfectly and right on schedule. That's despite the fact that Keck — named for W. M. Keck, founder of the Superior Oil Company, and the donor of $70

SPIRAL GALAXY NGC 1232 glows in pop-art colors in the first image made with the world's largest telescope, the Keck reflector átop Mauna Kea, Hawaii. Background: The Keck dome sits isolated at sunset, ready to revolutionize ground-based astronomy. All images courtesy CARA, Keck Foundation.





THE KECK TELESCOPE combines thirty-six hexagonal mirror segments that will together create the world's largest telescope for optical and infrared research. The mirror segments together create a surface equal to a single, 10-meter mirror. Right: A view from below the mirror shows the positions of the 36 hexagonal pads.

million toward construction of the world's largest scope — utilizes an unorthodox array of mirror segments, mounted on special hardware and driven by computer, to produce in effect a single, giant mirror. Keck's early reviews are glowing — and they can be traced back to a single evening last autumn.

On the cool Hawaiian night of November 24, 1990, the giant eye peered skyward and captured an image for the first time. After months of testing, installation, and experimentation, astronomers decided it was time to make an official first-light photo. In the Keck dome on the summit of Mauna Kea, technicians carefully checked the readiness of the telescope, its computer tracking mechanism, and an elaborate charge-coupled device attached to the rear of the telescope. Then they aimed the goliath at the galaxy NGC 1232 in Eridanus and made a series of short exposures. The telescope imaged the galaxy in unprecedented detail, showing the galaxy's bright core, winding spiral arms, dust lanes, and knotty patches of star clouds. It was truly an image that showed great promise for a great telescope.

Although only nine of the Keck telescope's 36 mirror segments were in place, astronomers wanted to create a first-light image largely for sentimental reasons. With one-quarter of its mirror segments in place, the Keck telescope effectively equals in light-gathering power the 200-inch Hale telescope on Palomar Mountain, California, currently the largest fully functioning telescope. (Some CARA astronomers have called the Keck first-light image the "Palomar portrait.") When it is completed, the Keck telescope's 36 mirrors will cover an area spanning 33 feet (10 meters), an area four times larger than that of the Hale telescope. The mirrors will be electronically controlled to an accuracy of one-millionth of an inch as the telescope slews across the sky.

For now, Keck scientists continue to ready the telescope with complete confidence. "Achieving first light tells you that the fundamental character of the telescope is correct," says Edward C. Stone, chairman of the board of CARA. "It doesn't mean that you have necessarily solved all the last, little, tiny details — that's what you do in the year or so following first-light — but it tells you that you have a concept that works." According to Jerry Nelson, project scientist for the Keck telescope, first-light "told us that the Keck instrument has passed several important tests, removing any doubt about the telescope's segmented mirror design. It tests our ability to fabricate the optics, to polish the surfaces, and to make the active control system work properly. In addition, it tells us whether you can drive the telescope around and whether that will produce vibrations in the primary mirror. Overall, the images produced by the mirror are a very strong test of the viability of the approach."

In the wake of the first-light test, work continues at a brisk pace within Keck's dome. Only 23 of the 36 mirror segments have been polished so far, and a battery of tests will be conducted on the giant instrument over the coming spring to ensure that all is well. Should work continue on schedule, the Keck telescope will be fully operational by the end of 1991 and will dramatically show that astronomy with large ground-based telescopes has a big future. □

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In an unbiased test of six manufacturers in the November 1990 issue of *Sky and Telescope*, the Parks mirror provided the best overall optical figure. The Parks mirror had no astigmatism, the smallest surface error, and the smallest wavefront error. The test concluded that this mirror would give "essentially perfect star images"' and that this was the only mirror to exceed the Rayleigh limit of optical performance.

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Life Near the Center of the Galaxy

How different would life be if we lived on a planet near the center of the Galaxy?

by Neil F. Comins

Night. The Sun and Moon are down, and stars by the thousands twinkle serenely against the ebony darkness of space. The constellations stand out, challenging your imagination; over there is the Big Dipper; there, the cross in Cygnus; there the "W" in Cassiopeia. Overhead the soft white of the Milky Way catches your attention. You try to see individual stars in the hazy glow. It's the kind of warm and fuzzy evening astronomers thrive on.

As it happens, we have the luxury of such peaceful surroundings because we live in a very quiet suburb in the Galaxy, away from the bustle of star formation and colliding interstellar gas clouds. But what if we were to move the solar system closer to the center of our Milky Way?

Currently we live in an area that is just right for life. It's far enough out in the 'burbs — about 25,000 light-years from the Galaxy's nucleus — that we have relatively little to worry about. There are no frequent, cataclysmic brushes with stars rocketing through our solar system. There are no noxious interstellar clouds of gases or toxic blankets of dust cascading through our environment. But what if Earth orbited a star just 10,000 light-years out from the galactic center? What would you see if you stood on a lonely mountaintop on an Earth closer to the galactic center of the action? A sky filled with bright neighbor stars with frequent, nearby supernovae? A frozen blanket of glowing gas draped from horizon to horizon? Strange and new patterns of stars forming curious and unrecognizable constellations?

Our Present Home in the Galaxy

Before we make the hair-raising 15,000 light-year journey inward, consider our group of planets as a whole. It is composed of the Sun, its

What would you see if you stood on a lonely mountaintop on an Earth closer to the galactic center?

host of nine planets, over fifty moons (the latest found in 1990), and miscellaneous debris. The rocky and metallic debris is in the form of boulders, called asteroids, and the remainder is frozen ices of water, carbon dioxide, methane, and ammonia — comets. The system is disk-shaped with all the planets orbiting the Sun in the same direction. Most asteroids are also in the disk, but comets appear to form in a spherical distribution around the Sun called the Oort cloud. There may be as many as a trillion comets orbiting the Sun, some drifting lazily out halfway to the nearest stars.

The solar system orbits the center of a disk-shaped Galaxy containing upward of two hundred billion stars. The disk is centered on a smaller sphere of stars called the nuclear bulge. A halo of globular clusters, giant balls of old stars, extends much farther out than the disk. Seen from above, the Galaxy has several spiral arms that swirl outward from the nuclear bulge.

The solar system is moving at about 540,000 miles an hour in its orbit. As we travel around the Galaxy we encounter the spiral arms, which move around the galactic center at half of our speed. These bright regions are deceiving. They are not rigidly rotating patterns of stars, but more like slow moving spiral-shaped waves. At any one time the Galaxy's spiral arms have only about 5 percent more stars and interstellar gas than we find around us right now. However, this slight excess density provides enough gravitational force to kick interstellar gas into condensing and forming new stars. Some of these new stars are particularly bright and, therefore, they highlight the spiral arms.

Most of the stars and gas in our Galaxy have the same orbital speed as the Sun. Since the gas that forms the new stars is moving faster than the spiral arms, you might reasonably expect that the bright stars accenting the spiral arms will migrate away from the arms, washing out the spiral structure. However, this doesn't happen because these bright, massive stars live only a few million years before exploding as supernovae, the most awesome displays of energy known. These explosions occur before the stars drift out of the spiral arms, thus preserving the integrity of the spiral structure of the Galaxy for billions of years.

To get a perspective on the changes that lie in store on our new Earth, for each of the stars we can see with the naked eye today, there are over thirty million stars in our Galaxy we can't see. The individual stars you see before you tonight are all nearby, within three hundred light-years. You can see about 3,000 stars on a particularly clear night. The Milky Way light we see now in the sky is a combination of starlight and light that has been scattered by interstellar gas and dust. This gas and dust indicates the edges of nearby spiral arms.

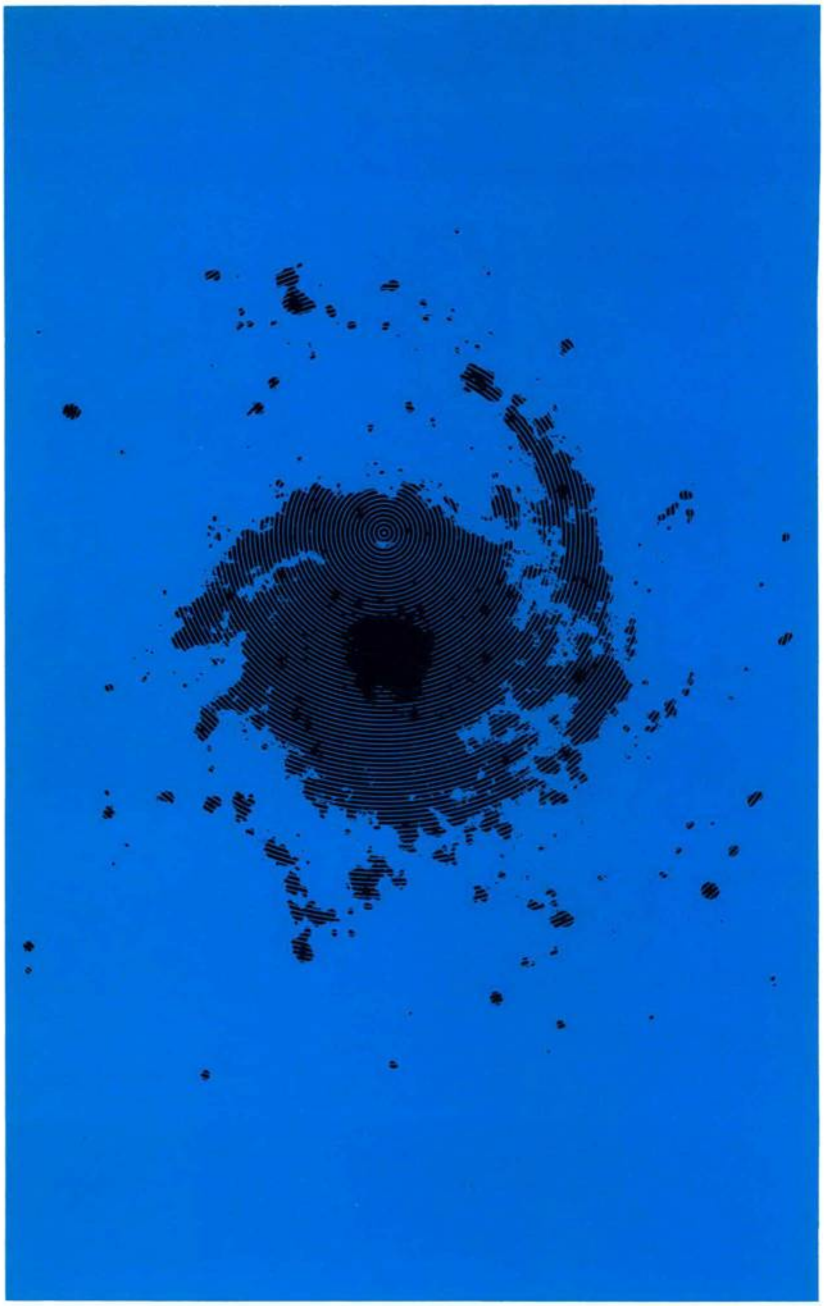
Living in a New Neighborhood

Our solar system's circular orbit is about 200,000 million million miles from the center of the Galaxy, which is presently located toward the direction of the constellation Sagittarius. If we could travel at the speed of light, it would take 29,000 years to reach the galactic center.

So let's move the solar system. But let's imagine that instead of being 29,000 light-years out, we are just 10,000 light-years from the galactic center. Why not go right to the center? Because it would be the end of us all. There is mounting evidence that the center of the Milky Way Galaxy harbors a black hole — a mysterious region where the laws of physics as we know them behave strangely and break down. This is surrounded by a maelstrom of gas, dust, and stars driven wild by a gravity sink so dense it contains more than a million solar masses of matter. The intensity of the radiation there, the tug of the black hole and the many nearby stars, the strong magnetic fields, and the dense gas clouds make this a particularly inhospitable place to raise a planet populated by creatures of flesh and blood.

At our new home 10,000 light-years from the Galaxy's center, we are still in a spiral arm, but only about 3,000 light-years beyond the edge of the nuclear bulge. We couldn't have seen this place from our old home because of the obscuring gas and dust. The most obvious change in the night sky is the new pattern of stars. None of the present constellations, or indeed any of the familiar stars, are visible now. But we see many more stars at our new home because stars concentrate toward the center of the Galaxy.

Out in the suburbs of the Galaxy we lived among one star per 275 cubic light-years. Now there are five times as many stars surrounding us, or one star per 55 cubic light-years. The new night sky is much brighter than the old one. The extra brightness comes in part from light reflected by the interstellar clouds that we also see in higher numbers. And from time to time the new sky will increase still more in brightness as it slowly moves through spiral arms.



We will now pass through spiral arms more frequently because our solar system is moving as fast as it was back in the outskirts and because the spiral arms here are closer together than the ones out in the 'burbs. The result is that we will now go crashing through them much more often, and since there is a greater fraction of intrinsically bright (massive) stars in spiral arms than between them, on average the stars near us are now brighter than they were back at the old homestead. One of these stars is so bright we can routinely see it during the day, except when the Sun comes within a few degrees of it.

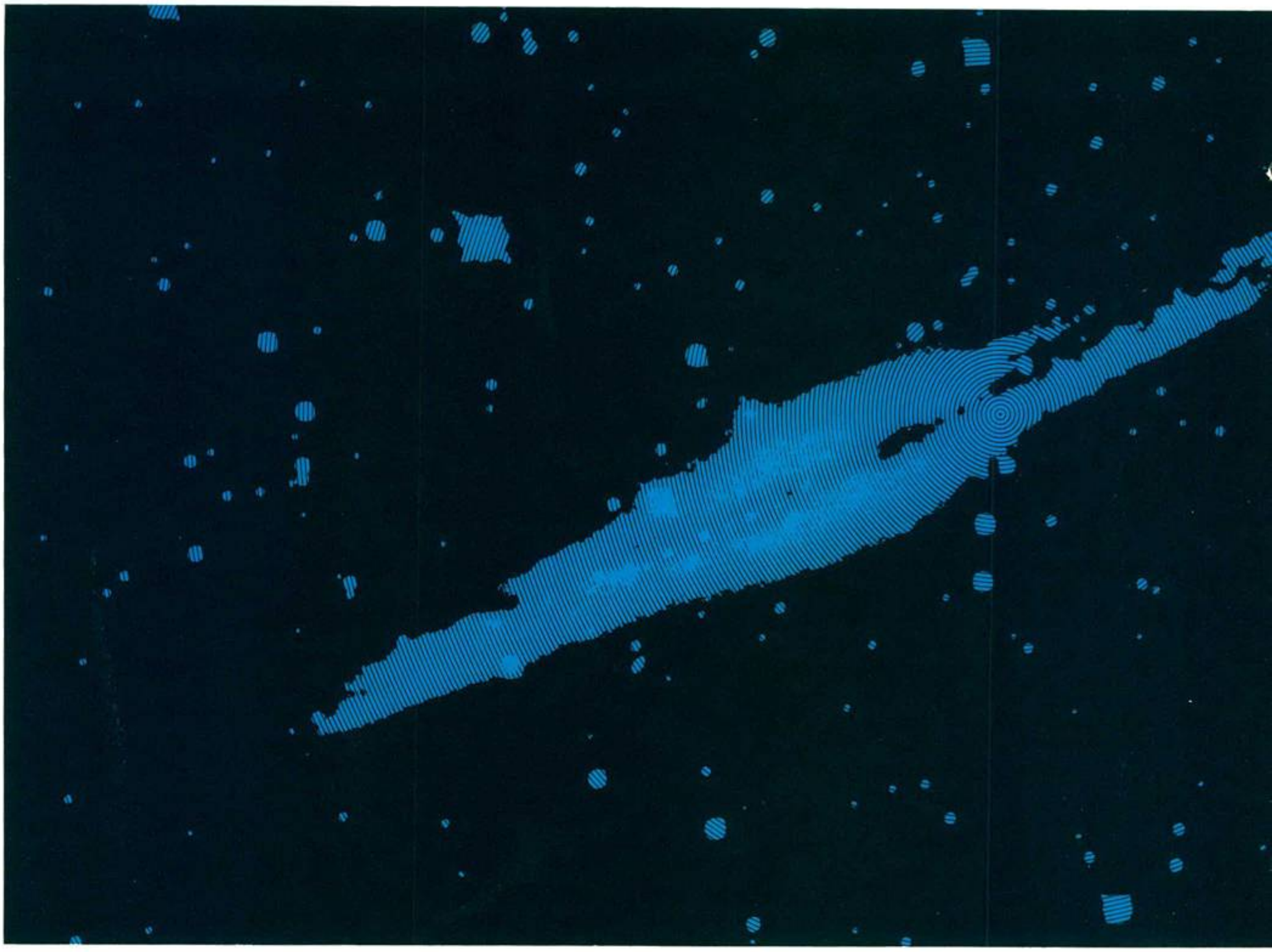
Our nights are now rarely as dark as they were back home in the big sky country, and millions of years may pass during which stars in our sky are so bright that night is never very much darker than day. Suppose, for example, that a Rigel-type star slowly cruises through the north pole, like some kind of super-Polaris. When that happens there will be no darkness at night in the northern hemisphere of Earth throughout the year. If it passes over our equator, then for six months out of each year while that star is up at night, every place on Earth will be without darkness. During the other six months the star will be visible during the day.

A Cloudy Sky Ahead

Besides spending more time in a spiral arm, we inhabitants of the new solar system will frequently experience passing through a cloud of interstellar gas and dust. In fact, astronomers back on the old Earth observed a huge mass of gas some 10,000 light-years out from the galactic center, flowing outward from the center of the Galaxy at 110,000 miles per hour. Extrapolating from images of gas clouds made from the old home, astronomers predicted that when we arrived here our sky would be filled with shimmering wisps of nebulae — and they were right. Unfortunately for deep-sky observers, we see what amounts to never-ending, but unmoving, aurorae far above the Earth's atmosphere.

Will some of this gas from the clouds reach Earth's surface? That depends on the density and speed of the gas. In the first place, interstellar clouds contain mostly hydrogen, and the gas density in these clouds is typically far lower than the density of our atmosphere — anywhere from one to a thousand atoms per cubic centimeter in the interstellar clouds. Nonetheless, some small fraction of the hydrogen and other atoms and molecules will become chemically incorporated into our upper atmosphere.

Our Sun might give us some protection from the clouds. To see how this works, note that sunlight and the flow of particles from the Sun, the solar wind, exert outward pressures on interstellar gas and dust,



blowing much of it away from the inner solar system. This happened continuously in the old solar system. Most of these particles were trapped above our atmosphere by the magnetic field that was generated by Earth's rotation. The particles orbited in the magnetic Van Allen belts. Occasionally these belts overloaded and the trapped particles cascaded Earthward, creating an aurora.

Now, if the outward pressure from the Sun is strong enough, it will push the clouds away and their gases won't reach Earth. If the solar wind is too weak, we will have numerous aurorae as cloud particles frequently swamp the Van Allen belts. We'll be living in a hole in the passing cloud or simply bathing in its gases.

The elements besides hydrogen in the clouds have different isotopic abundances than they do on Earth. In other words, each element can exist with different numbers of neutrons in their nuclei. These are called different isotopes of an element and the contribution of elements to Earth from the cloud will cause a shift here in the ratios of isotopes of different elements as these materials drift down through our atmosphere. The effects of different isotopes on chemistry and biology would depend on the cloud's chemistry. If changes result from the inflow of cloud material, they will take millions of years to occur, because it will take that long for serious quantities of extraterrestrial atoms to collect here. Considering the low densities of interstellar clouds, it's unlikely these changes would be fatal to life.

Some of the clouds have relatively high concentrations of complex molecules. If we pass through one of the clouds containing millions of gallons of ethyl alcohol, or the preservative formaldehyde, or smelly hydrogen sulfide, or ammonia, we'll be in big trouble because there are also some potentially hazardous molecules found in these clouds. These include, among others, various types of toxic cyanide as well as carbon monoxide, which will bind with hemoglobin in our blood and thereby prevent oxygen from reaching cells in our body. Some clouds also contain methyl alcohol, which when ingested can produce blindness and death. While the density of any of these substances in interstellar clouds is minuscule by Earth standards, the cumulative effects of a rain of ethyl alcohol for millions of years would certainly not be beneficial.

A Crowded Life

What about the number of nearby stars and their gravitational effect on our new Earth? Will the Sun be in danger of hitting another star? No. First of all, at any place in the Galaxy stars near each other orbit around the center of the Galaxy with about the same speed. The relative motion of stars is so small and the space between the stars is so large that in the lifetime of the

Millions of years may pass during which stars in our new sky are so bright that night is never much darker than day.

universe the chance of a collision between the Sun and another star is less than one in a billion.

On the other hand, pairs of stars do pass near enough to each other from time to time that the gravitational field of each affects the planetary system of the other. What can happen during such a near hit? The intruder's gravitational force would certainly change planetary orbits, possibly even ripping some of the outer planets away from the Sun. It would also disturb the Oort cloud. If current theory is correct and every star has a comet cloud, it's probable that some of the comets either from the Oort cloud or from the intruder's entourage would be propelled in toward Earth. With a lot of new comets coming in, the possibility of one of them hitting Earth would increase dramatically. This scenario may have happened to the old Earth, as suggested by mass extinctions earlier in geologic history.

These dynamics are more likely where there are more stars. Increasing the frequency of stellar near hits also increases the chance that Earth might be pulled hard by an interloper and our orbit around the Sun made so elliptical that the climate would vary dramatically.

On old Earth, our seasons were caused by the changing angle of sunlight throughout the year because Earth's axis of rotation was tilted 66.5° compared to the plane of our orbit around the Sun. When the north pole tilted toward the Sun, the Sun was "up" in our sky longer each day, and vice versa. On old Earth, Earth's distance from the Sun varied by only 3 percent throughout the year, and the effect of changing distances on weather was almost completely nullified by local atmospheric phenomena like ocean currents, winds, and storms.

But now if our orbit becomes more elliptical, the effect of the changing distance will have a profound impact on Earth, perhaps throwing the entire planet into colder winters and hotter summers, and making life much harder to sustain. The challenges for nature to preserve life would be far greater.

All stars evolve, and the bright, massive ones eventually explode as supernovae. If this happens to a star near our new Earth, where there are many more massive stars that could become supernovae, the stream of high-energy radiation and high-speed particles from the explosion could seriously damage Earth's biosphere. Lethal mutations of plants and animals would probably occur. Cancer rates would soar. Depending on how close the star is to us, part of our atmosphere might even be stripped away. At the very least, the supernova will be visible during the day and will be brighter than the Sun.

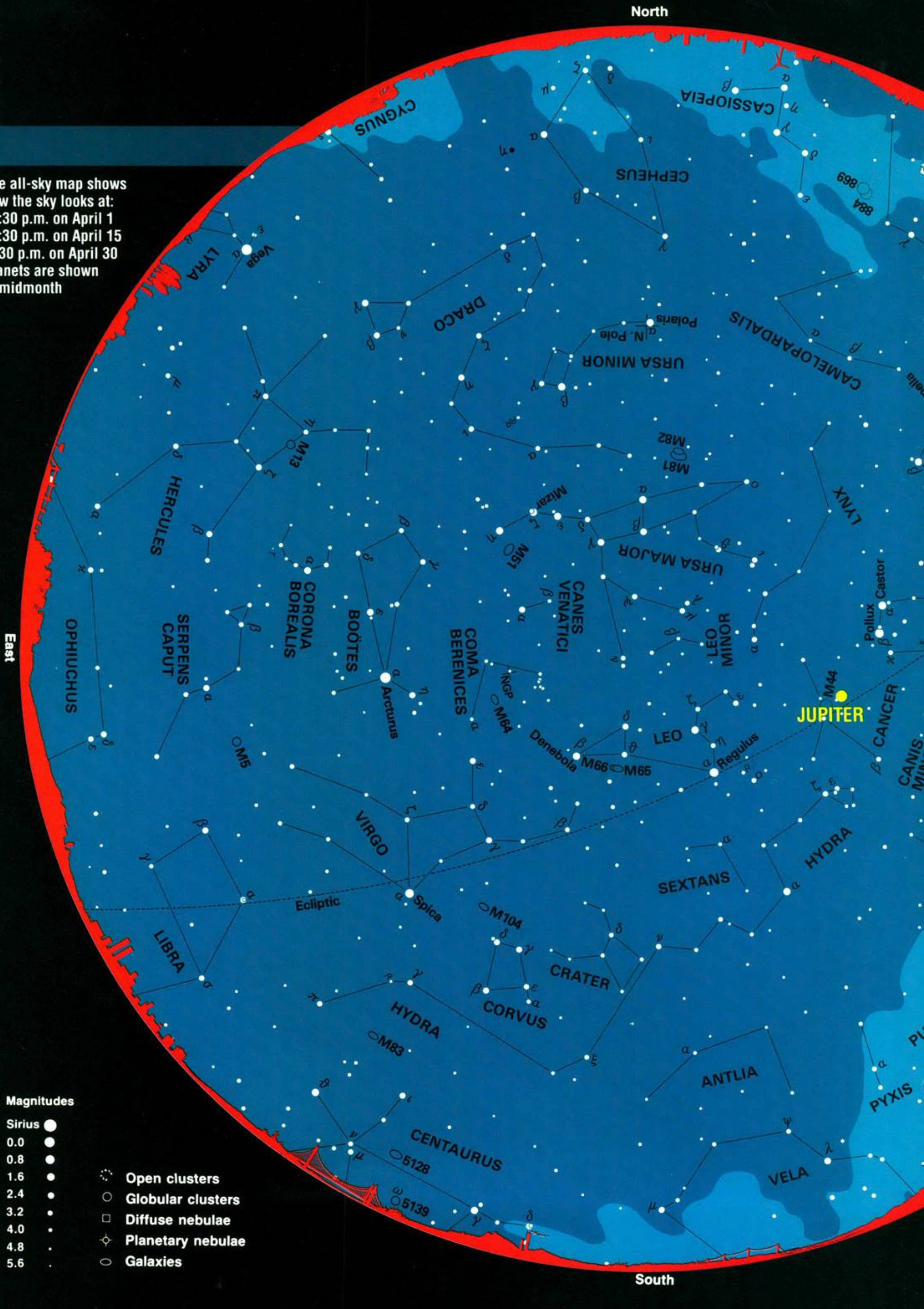
At our new location, the likelihood of other intelligent beings existing somewhere nearby is higher than it was on old Earth because of the increased density of stars. If Earth weren't discovered by the aliens in a survey, the aliens would eventually discover us by our radio transmissions. On old Earth, after a hundred years of broadcasting television and radio signals, we left behind a sphere of space centered on Earth filled with "I Love Lucy" and "The Lone Ranger." "Teenage Mutant Ninja Turtles" has already reached the nearest stars. There are about 15,000 stars in that sphere. At our new location there are some 75,000 possible neighbors who might discover us.

As I stood on the new Earth watching the brilliantly luminescent clouds in the sky and the thousands of bright stars, I wondered most about the possibility of being poisoned by the substances contained within the clouds. How amazing it is that the prettiest things in our new sky might also kill us. Then, slowly, my vision of the sky dissolved and I heard a loud buzzing.

It was all a dream, and I awoke in the same bedroom on the same old Earth I had always known. The only thing I could think was that, although life might be much more difficult and dangerous nearer the center of the Galaxy, it might also hold the key to contacting other civilizations. By living out in the 'burbs, we may be missing the greatest thrill a civilization could hope for. ☐

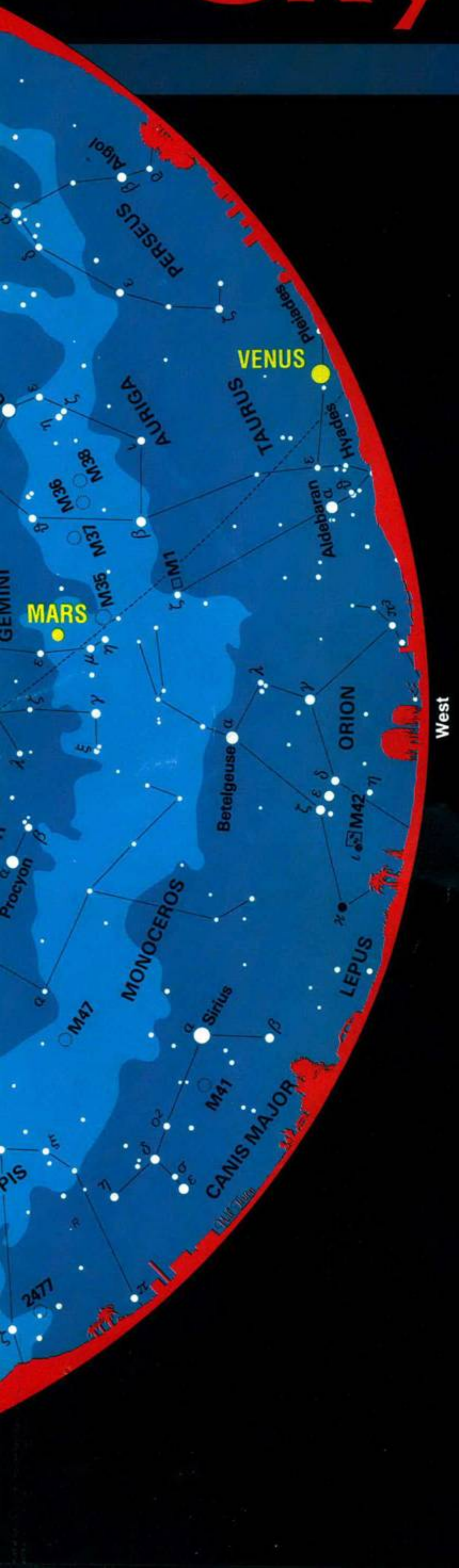
Neil F. Comins is a professor of physics at the University of Maine in Orono. His last article was "The Earth without the Moon" in the February 1991 issue.

The all-sky map shows how the sky looks at:
10:30 p.m. on April 1
10:30 p.m. on April 15
9:30 p.m. on April 30
Planets are shown at midmonth


North
South
East
CYGNUS
CASSIOPEIA
CEPHEUS
869
884
LYRA
Vega
DRACO
Polaris
N. Pole
URSA MINOR
CAMELOPARDALIS
M13
HERCULES
M82
M81
Mizar
M51
URSA MAJOR
LYNX
CORONA BOREALIS
BOÖTES
CANES VENATICI
LEO MINOR
SERPENS CAPUT
OPHIUCHUS
COMA BERENICES
Arcturus
NGP
M64
M44
JUPITER
CANCER
Castor
Pollux
M5
Denebola
M66
M65
LEO
Regulus
CANIS MI
VIRGO
HYDRA
SEXTANS
Ecliptic
Spica
M104
LIBRA
CRATER
CORVUS
HYDRA
M83
ANTLIA
PYXIS
PU
CENTAURUS
5128
5139
VELA
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

April 1991


Algol
PERSEUS
Pleiades
VENUS
AURIGA
TAURUS
Hyades
M38
M36
M37
Aldebaran
M1
GEMINI
MARS
M35
ORION
West
Betelgeuse
M42
Procyon
MONOCEROS
LEPUS
M47
Sirius
M41
CANIS MAJOR
2477

LYRIDS PEAK ON APRIL 22

Meteors will streak across the predawn sky on April 22 as the annual Lyrid meteor shower reaches its peak. You can expect to see about fifteen meteors per hour from a dark sky site that morning.

TWO STRIKING CONJUNCTIONS

Both Venus and Mars make eye-catching appearances near prominent star clusters this month. Brilliant Venus comes within 3° of the Pleiades in the evening sky on April 12, while ruddy Mars passes 1° north of the open cluster M35 in Gemini on the evening of April 6.

MORE JOVIAN MUTUAL EVENTS

The rate of mutual eclipses and occultations among Jupiter's Galilean satellites remains high this month. Many of these events should be spectacular, but perhaps the most dramatic occurs on April 15/16, when Ganymede eclipses Europa and Europa almost disappears.

CERES AT OPPOSITION

The largest asteroid is an easy object to find in binoculars or a telescope this month. The 7th-magnitude minor planet reaches opposition on April 17 among the stars of the constellation Virgo.

Calendar of Events

3 The Moon passes 1.1° north of Antares, 10 p.m. EST

5 The Moon is at apogee (251,223 miles from Earth), 4:07 p.m. EST

7 Last Quarter Moon is at 1:45 a.m. EST

8 The Moon passes 1.4° north of Saturn, 5 p.m. EDT

14 New Moon is at 3:38 p.m. EDT
Mercury is in inferior conjunction

17 Ceres is at opposition
The Moon passes 2° north of Venus, noon EDT
The Moon is at perigee (227,074 miles from Earth), 1:07 p.m. EDT

19 The Moon passes 0.6° south of Mars, 8 p.m. EDT

21 First Quarter Moon is at 8:39 a.m. EDT
The Moon passes 1.9° south of Jupiter, 3 p.m. EDT

22 Lyrid meteor shower peaks

28 Full Moon is at 4:58 p.m. EDT

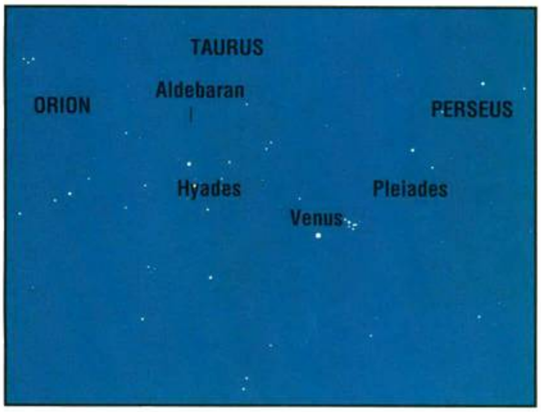
THREE PLANETS IN THE TWILIGHT

If you look to the west after sunset this month, you'll be greeted by a trio of bright planets. Venus is the brightest and lies closest to the horizon. Mars is relatively faint and about halfway up in the west. Jupiter is much brighter than Mars (though noticeably fainter than Venus), and is highest in the sky. Although the calendar says spring, the planets are framed by the bright stars normally associated with the evening sky in winter.

Amid this confusion of stars, the planets are easy to locate. Venus, at magnitude –4.0, is far brighter than any star. Jupiter is also exceedingly bright and, at magnitude –2.2, about twice as bright as the brightest star, Sirius. Mars shines comparatively faintly at magnitude 1.2, but is quite easy to spot between Jupiter and Venus, along the invisible arc of the ecliptic.

In fact, the positions of the planets this month enable you to trace the whereabouts of the ecliptic in our sky. Just draw an imaginary line between them. The planets aren't scattered in the sky randomly because all the planets in our solar system orbit the Sun in nearly the same plane — the ecliptic. From where we stand on Earth, these great worlds appear as remote lights strung in a line across our sky.

The stage is now set for Jupiter, Mars, and Venus to put on a wonderful show. They'll do so in the coming months as they move closer to one another. All three are traveling eastward relative to the background stars. Venus, the innermost of the three planets, moves faster than Mars, which in turn moves faster than Jupiter. By June, the trio of planets will appear dazzlingly close together, in one of the prettiest sky events for this year.



VENUS PASSES THE PLEIADES on April 12, when the two lie less than 3° from each other in the western evening sky. In binoculars the conjunction will look similar to the one George R. Viscome photographed in April 1988 (below).

VENUS CATCHES THE PLEIADES CLUSTER

As Venus moves east against the starry backdrop, it passes close to the Pleiades star cluster. The two are closest on the evening of April 12, when they are separated by less than 3°, but the two make a stunning pair for several days before and after that date. Use binoculars to get the best view of the close passage.

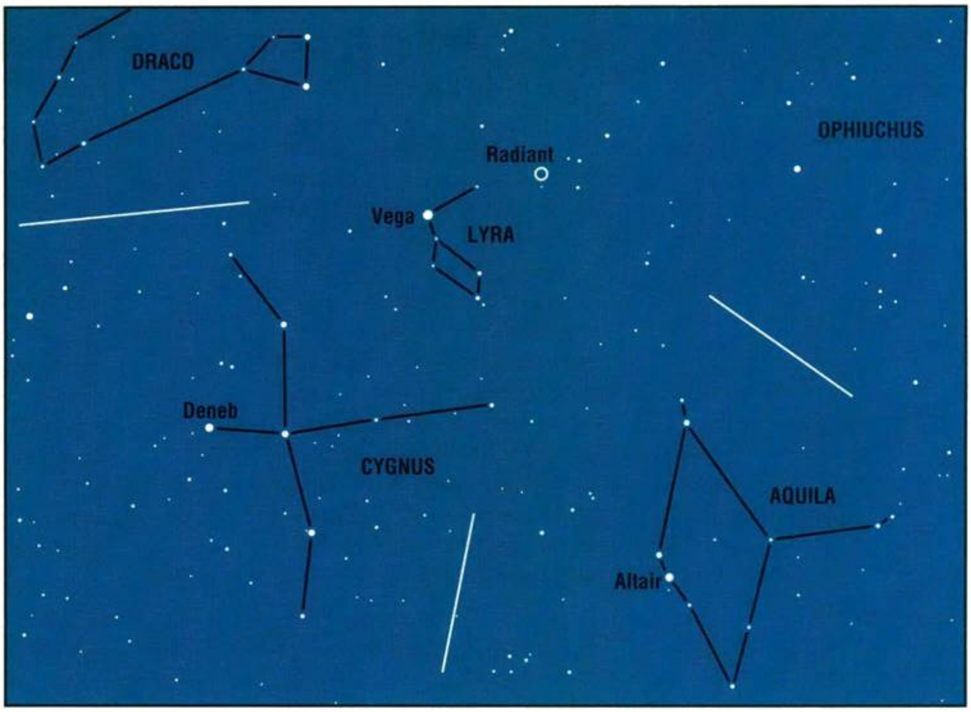
FAVORABLE CONDITIONS FOR THE LYRIDS

The Lyrid meteor shower peaks this year on the morning of April 22. The First Quarter Moon sets an hour or two after midnight that day, leaving the sky dark during the prime observing hours before dawn. You can expect to see about 15 of the typically bright Lyrid meteors per hour until morning twilight interferes.

The Lyrid shower isn't spectacular in most years, but it has produced some brilliant displays in the past. The most recent occurred in 1982, when for a short time meteors fell at a rate of 250 per hour. That's three or four times the average rate of the best annual showers. Unfortunately, such displays are few and far between. Some astronomers think that major Lyrid storms occur about every 60 years.

Like other meteors in annual showers, the Lyrids result from bits of cometary debris that vaporize in Earth's atmosphere. Chinese records show that the Lyrid shower was first observed in 687 B.C., which makes this the earliest major meteor shower to be recorded. Although Lyrid meteors have been seen for thousands of years, the comet that spawned them has been recorded at only one apparition, in 1861. Comet Thatcher takes about 415 years to travel once around the Sun.

The Lyrids radiate from a point on the border between the constellations Lyra and Hercules, southwest of the bright star Vega. But don't think that you have to stare at this point in the sky to see the meteors. In fact, most meteors are seen some distance away from their radiant point. Just relax and watch as much of the sky as you can comfortably. As with any meteor shower, try to view the Lyrids from a site far removed from city lights.



LYRIDS STREAK through the predawn sky on April 22 at a rate of about fifteen meteors per hour. The meteors appear to radiate from a point in the constellation Lyra, which lies high in the east before dawn.

APRIL'S PLANETS

Mercury is visible low in the west about 30 minutes after sunset during the first few days of April. It lies well below the other three planets in the evening sky, however, and is much more difficult to see. To find the 1st-magnitude planet, scan near the horizon with a pair of binoculars. By the end of the first week of April, Mercury is lost in the Sun's glare. It passes between the Sun and Earth on April 14.

While Mercury approaches the Sun, Venus continues to move away from it. The brightest planet now sets nearly three hours after the Sun and more than an hour after the end of twilight. It will edge a bit farther from the Sun between now and June, when it reaches greatest elongation — its maximum apparent distance from the Sun.

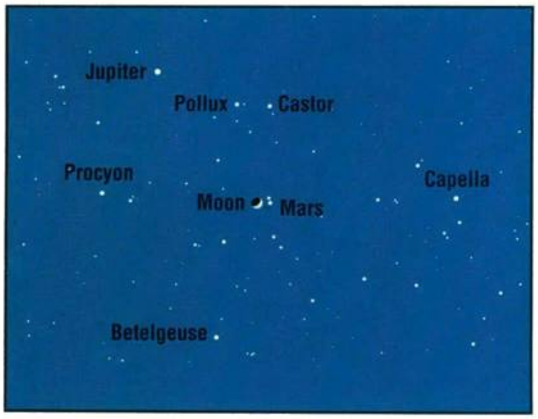
Venus passes a bit under 3° from the dipper-shaped Pleiades star cluster on April 12 and remains in the cluster's vicinity for several days afterward. That makes for a nice grouping of objects when the waxing crescent Moon passes by at midmonth. The Moon appears below and to the right of Venus on the evening of April 16 and on the following evening appears above the bright planet.

Mars moves from the constellation Taurus into Gemini in early April. The 1.2-magnitude planet is now about midway in brightness between the two brightest stars in Gemini, Castor and Pollux. Be sure to watch for the Red Planet on the evening of April 19, when it lies only about 1° from the waxing crescent Moon.

Jupiter, which still lies in Cancer, is high in the south at sunset and sets well after midnight. The First Quarter Moon takes two days to traverse the distance from Mars to Jupiter across our sky. Thus the Moon passes close to Jupiter on the evening of April 21.

The only naked-eye planet visible in the morning sky now is Saturn. The ringed planet rises about three hours before the Sun and can be found in the south-southeast among the stars of Capricornus before dawn. Saturn is now at its faintest for the year, shining at magnitude

THE MOON AND MARS form a pretty pair low in the western sky on the evening of April 19.



0.7. It will brighten significantly during the coming months as it approaches opposition in July.

APRIL'S STARRY SKY

Last month I talked about the constellation Hydra, the Sea Serpent, a thin line of stars now stretched across the southern sky each evening. An acquaintance with Hydra isn't complete without an introduction to its two companion constellations, however. Crater the Cup and Corvus the Crow ride on the back of the serpent in its journey across the sky.

Look for these two small constellations on a moonless night from a dark country sky. Neither is very bright, but both have distinctive shapes that make them easy to recognize.

Corvus is a small, compact constellation in the shape of a lopsided square. You can find it in the southeastern sky on April evenings located about 15° southwest of Virgo's brightest star, Spica.

On old maps of the heavens, the crow is often shown pecking at the serpent. In this view the crow's beak is the faint star Alpha Corvi, or Alchiba, which points down from the square toward Hydra. Personally, I prefer to see the star Eta Corvi as the crow's beak. This star points northeastward toward Spica. To me, the crow seems to be admiring Virgo.

Skywatchers throughout history have seen a bird in this pattern of stars. The Chinese called Corvus "the Red Bird." The Romans and Hebrews called it "the Raven." The constellation has a friendly look, and its stars are easy to find. Corvus, a sign of spring, rises in early evening at the time of year when earthly birds start returning from a winter in the south.

Meanwhile, Crater is located to the west of Corvus. It really looks like a cup or bowl, balanced on the back of the sea serpent.

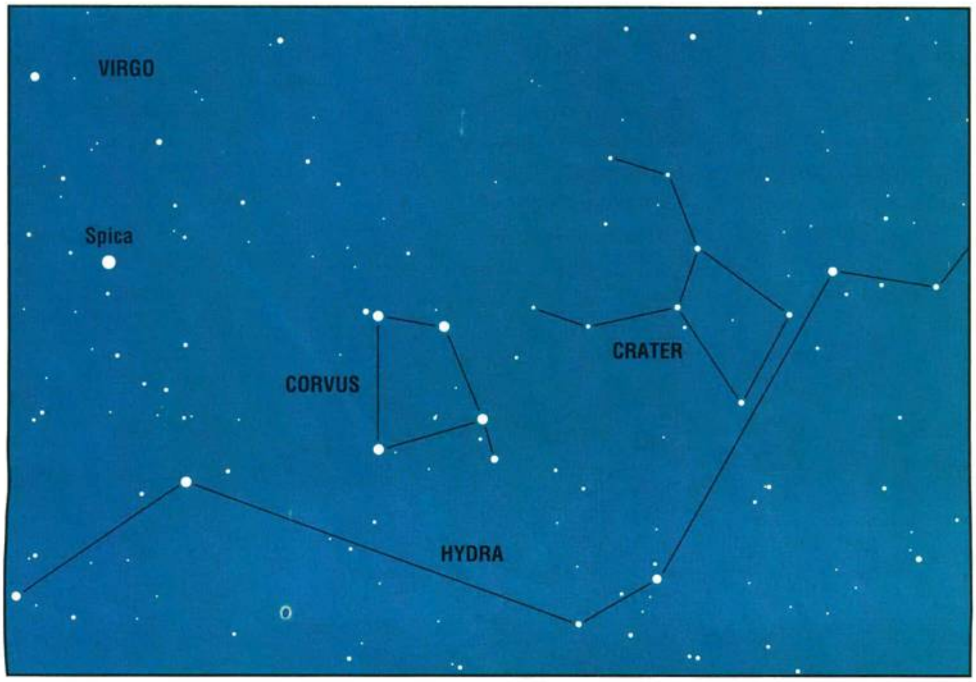
It looks like that, assuming you can see Crater at all! This constellation is quite faint, with its brightest stars shining at about 4th magnitude. Some modern stargazing books ignore it entirely, even though it's an interesting star pattern with a fascinating history.

Very early stargazers identified Crater with the "vault of heaven," or dome of the sky. As seen from the Northern Hemisphere, the bowl is sitting upright, but it's possible to imagine it turned upside-down as a microcosm of the heavens.

It used to be said that spring storms originated in the constellation Crater. Hydra and Corvus are also identified with storms. Hydra is sometimes seen as a storm and ocean monster. Corvus is sometimes called "the Great Storm Bird."

In old star atlases, the constellation Crater is often pictured as an elaborately decorated urn, with curved handles on either side. In a very dark sky, when many fainter stars become visible, it's possible to understand what the early constellation-namers had in mind. Not so with these handles for the cup. Early Romans are suspected of having added the handles for the convenience of Bacchus, the god of wine, who was said to drink from Crater. □

CORVUS AND CRATER ride across the sky on the back of the sea serpent Hydra. You can find these constellations about 30° above the southern horizon late on April evenings.



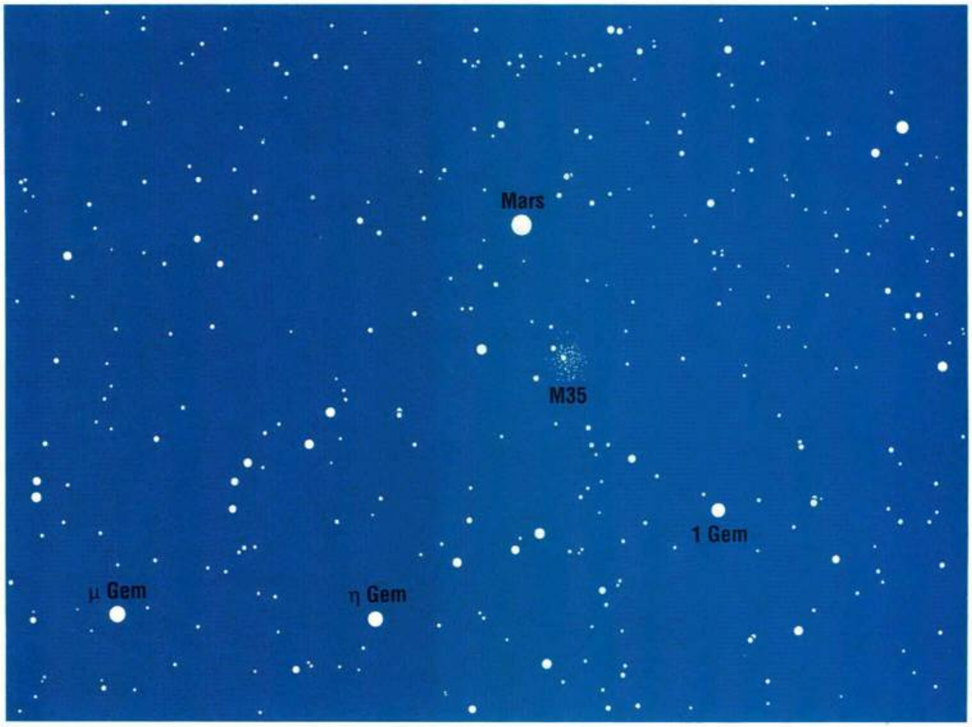
Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.

Through the Eyepiece *by* Rick Shaffer

MARS UPSTAGES A MESSIER-LIST CLUSTER

During the first week of April, the otherwise lackluster Mars will pass north of the open star cluster M35 in Gemini, missing it by less than 1°. It will be a beautiful sight at low power. If you repeatedly photograph Mars and the cluster together over several hours, you can flip from one photo to the next to show motion. A 500mm lens on a 35mm camera will do the trick neatly. To be sure M35 records, make each exposure about 10 minutes long on fast film. (Mars, which shines at magnitude 1.1 at the time, will be overexposed.)

As you view the event, you might relish the irony of what you are seeing — the bright object which seems to dominate the scene actually pales in comparison to the cluster of 200 stars whose diameter is about 45". Mars is in our celestial backyard, lying only about 13 light-minutes away. M35, however, is 2,800 light-*years* distant and roughly 30 light-years across. The total brightness of the stars in M35 is equal to that of 2,700 Suns!



MARS MEETS M35 in western Gemini on the evening of April 6. The two objects, which lie just 1° from each other, can best be seen in a rich-field telescope.

MORE GALILEAN SATELLITE MANEUVERS

On April 25, Jupiter reaches quadrature, a configuration in which it stands 90° away from the Sun in the sky. This means that in a telescope Jupiter's disk will look a bit lopsided because we on Earth are viewing Jupiter from off to one side. (In effect, we are peeking a short way onto Jupiter's night side.) After April 25 and until Jupiter becomes lost in the ruddy glow of evening twilight in August, its disk will become more and more fully illuminated, as Earth, Jupiter, and the Sun move steadily into line.

Quadrature's big advantage for Jupiter watchers, however, is that the eclipses of the outer two Galilean moons occur off the eastern side of the planet. This means that you will see Ganymede and Callisto vanish into Jupiter's shadow (be eclipsed, in other words) soon after they emerge from behind Jupiter. This gives you two celestial shows, one right after the other.

In addition to the Galilean satellites' eclipses, transits, and occultations with Jupiter, the big moons also continue their series of eclipses and occultations with each other. Among the highlights you should try to view this month are the eclipses on April 9, 12, 16, 19, and 26. During each of these events the eclipsed satellite dims by at least 50 percent. The deepest eclipse of the entire series to date occurs at 5h30m UT (1:30 a.m. EDT) on the 16th, when Europa passes into Ganymede's shadow and nearly disappears from view. (All events visible this month from North America are listed in the table on page 59. For more information on the mutual events, see "Watch Jupiter's Moons Play Tag" in the January 1991 issue.)

If you notice steady images of Jupiter's 39"-diameter disk while you are out observing satellite events, increase the magnification up to what will retain the sharpness of the image, yet make it easy to resolve the details. If you can attain a power of 50x per inch of telescope aperture, you'll probably see as much as your telescope will ever show you.

Look for the Great Red Spot nestled in its hollow. (A light blue filter will help enhance the contrast.) Can you see any other spots? If the seeing is really good, don't mistake a transiting satellite for a small white spot floating along on Jupiter's cloud tops!

CERES AT OPPOSITION

It's rare that an asteroid escapes the customary slot at the end of this column, but on April 17 the first asteroid ever discovered — 1 Ceres — reaches opposition to the Sun in our sky.

Ceres was discovered in Taurus on the first day of the 19th century (January 1, 1801) by the Italian astronomer Giuseppe Piazzi at Palermo. Piazzi was not observing Taurus by chance. Rather, he had agreed to search that constellation for objects which did not "belong" there, as part of an international effort to find a planet whose orbit lay between those of Mars and Jupiter.

The search was coordinated by Johann Bode of the Berlin Observatory. He was convinced that a mathematical progression in the sizes of planetary orbits predicted the existence of a planet at a distance of 2.8 astronomical units (AU) from the Sun. This mathematical relation had been noticed earlier by another astronomer, Titius von Wittenberg, and today it is called the Titius-Bode law (although in truth to call it a law probably claims too much for it).

The relation describes the average distances of the planets from the Sun as expressed in AU. To see how it works, take a sheet of paper and write down the number series 0, 3, 6, 12, 24, 48, 96. (After 3, each new number is twice the previous.) Then add 4 to each of these numbers, which yields 4, 7, 10, 16, 28, 52, 100. Now divide each number by 10 and get 0.4, 0.7, 1.0, 1.6, 2.8, 5.2, and 10.0.

Titius noticed this series closely matched the actual distances of the planets then known. (The mean distances are 0.39, 0.72, 1.0, 1.5, 5.2, and 9.6 AU for Mercury, Venus, Earth, Mars, Jupiter, and Saturn, in that order.) But there was no planet at 2.8 AU where the series predicted one. Titius and Bode theorized that an as-yet unfound planet must fill that gap. That was what Piazzi and 23 other astronomers were trying to find by searching the zodiac and comparing what they saw at the telescope with the best available charts.

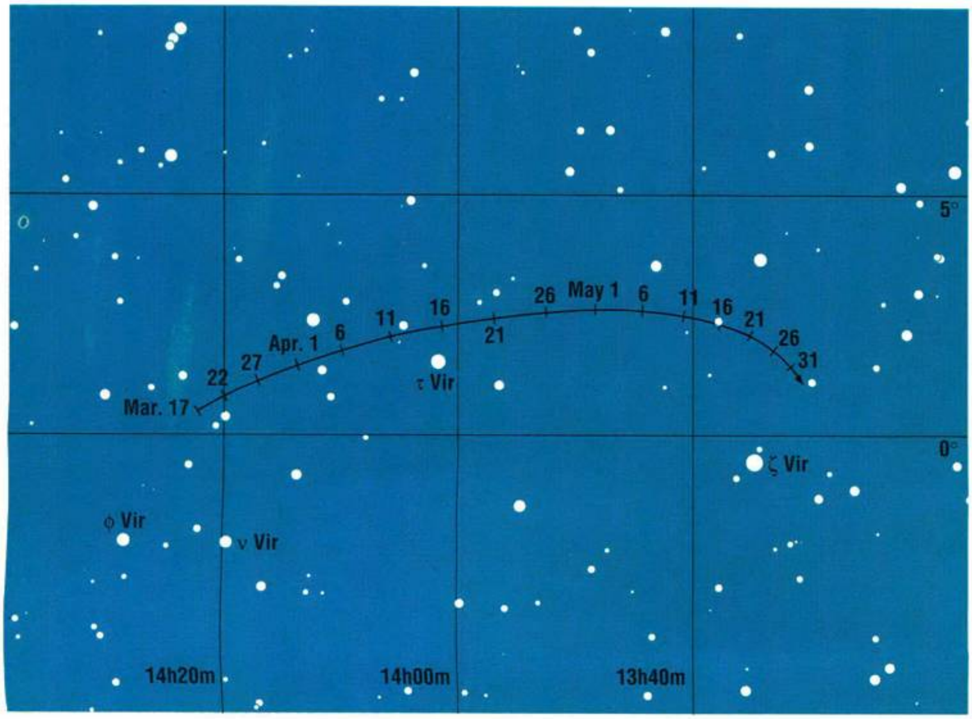
When Bode heard of the object Piazzi found, he asked a young German mathematician, Karl Frederich Gauss, to attempt to compute the object's orbit. But Gauss only had observations from January 1 to February 11, after which Ceres became lost in the solar glare. Using the methods then available, these weren't enough. To determine the orbit of Ceres, Gauss had to invent a new method, which is now the standard. His results gave a mean distance from the Sun for Ceres of — 2.77 AU.

Bode was certain the missing planet had been found. And until the next asteroid, 2 Pallas, was discovered two years later, it

COORDINATES FOR CERES

Date	R.A. (2000)	Dec.
Mar. 17	14h22.0m	0°32'
Mar. 22	14h19.8m	0°51'
Mar. 27	14h17.0m	1°11'
Apr. 1	14h13.6m	1°31'
Apr. 6	14h09.8m	1°49'
Apr. 11	14h05.7m	2°05'
Apr. 16	14h01.3m	2°19'
Apr. 21	13h56.9m	2°30'
Apr. 26	13h52.5m	2°37'
May 1	13h48.2m	2°40'
May 6	13h44.3m	2°38'
May 11	13h40.7m	2°32'
May 16	13h37.6m	2°22'
May 21	13h35.0m	2°07'
May 26	13h33.0m	1°48'
May 31	13h31.6m	1°26'

ASTEROID 1 CERES brightens to magnitude 7.0 as it comes to opposition this month. Ceres' positions are shown for 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT).



indeed appeared that the solar system was mathematically harmonious. But as more asteroids were discovered, astronomers realized that Ceres' 2.8 AU distance was a fluke. Most asteroids were orbiting in a thick torus (now called the asteroid belt), which is about 3 AU wide and occupies much of the space between Mars and Jupiter. Even worse for the missing body notion, there weren't enough asteroids to make up a planet: the mass of all the others equals only that of Ceres itself. This sealed the fate of a grand idea — a single large planet between Mars and Jupiter.

To see Ceres for yourself, start with the finder chart or table of coordinates on the opposite page. Since Ceres will shine at magnitude 7, you should have little trouble identifying it as the interloper in your field — exactly as Piazzi did in 1801. Wouldn't it be fun to step back 190 years and follow Ceres as the astronomers of yesteryear did, throughout this month and into the summer?

MUTUAL EVENTS OF THE GALILEAN SATELLITES

Date	Begin Time	End Time	Event	Type of Event	Light Loss	Distance
Apr. 5	1h20m	1h24m	Io Eclipses Europa	Partial	34%	1
Apr. 7	5h44m	5h48m	Europa Occults Io	Partial	4%	5
Apr. 7	7h37m	7h43m	Europa Eclipses Io	Partial	33%	4
Apr. 9	2h07m	2h15m	Ganymede Eclipses Europa	Partial	78%	6
Apr. 12	3h33m	3h38m	Io Eclipses Europa	Partial	50%	1
Apr. 14	7h59m	8h02m	Europa Occults Io	Partial	2%	5
Apr. 15	1h21m	1h45m	Ganymede Eclipses Callisto	Partial	43%	19
Apr. 16	5h22m	5h31m	Ganymede Eclipses Europa	Partial	97%	7
Apr. 19	5h47m	5h52m	Io Eclipses Europa	Partial	64%	2
Apr. 25	1h18m	1h23m	Europa Eclipses Io	Partial	12%	3
Apr. 26	8h02m	8h07m	Io Eclipses Europa	Annular	80%	2

Begin Time: Universal time at beginning of event. (Subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST. Subtract an hour less for daylight time.) **End Time:** Universal time at end of event. **Event:** The nature of the event and the satellites involved. **Type of Event:** Whether the event is partial, total, or annular. **Light Loss:** For eclipses — the percent of light lost by the eclipsed satellite at midevent; For occultations — the percent of light lost from the combined light of both satellites at midevent. **Distance:** The apparent distance of the satellite from Jupiter's center in Jovian equatorial radii.

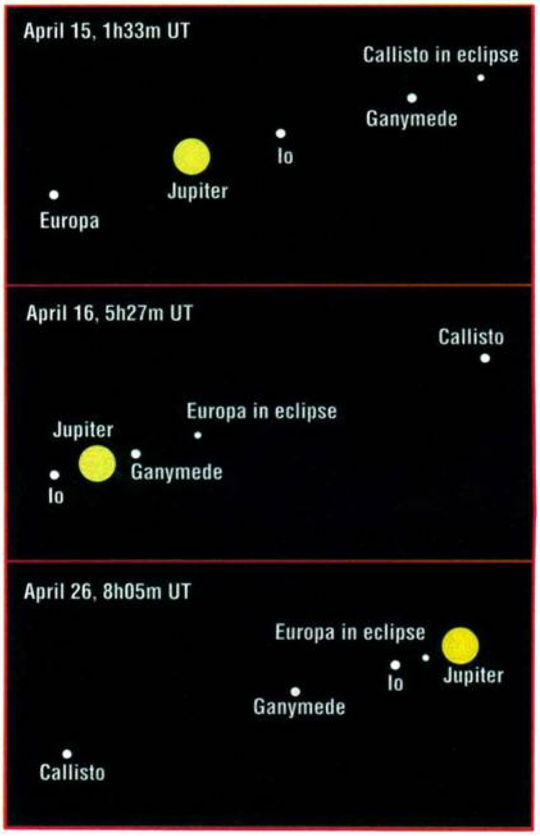
PLANETS IN THE EYEPIECE

Mercury finishes its excellent evening apparition early in April. It is definitely worth a look, because Mercury shows the largest change in phase during the last half of the apparition. Try to see how long into April you can keep viewing Mercury. By the 14th, this fleetfooted messenger reaches inferior conjunction with the Sun and passes into the morning sky for a truly poor apparition.

Venus makes little change in phase or position during April; the real show begins in May and continues into mid-summer, when the planet's position, phase, and brightness all change considerably. Use this month's views to give your sketching eye practice and to iron out the bugs in your astrophotography setup.

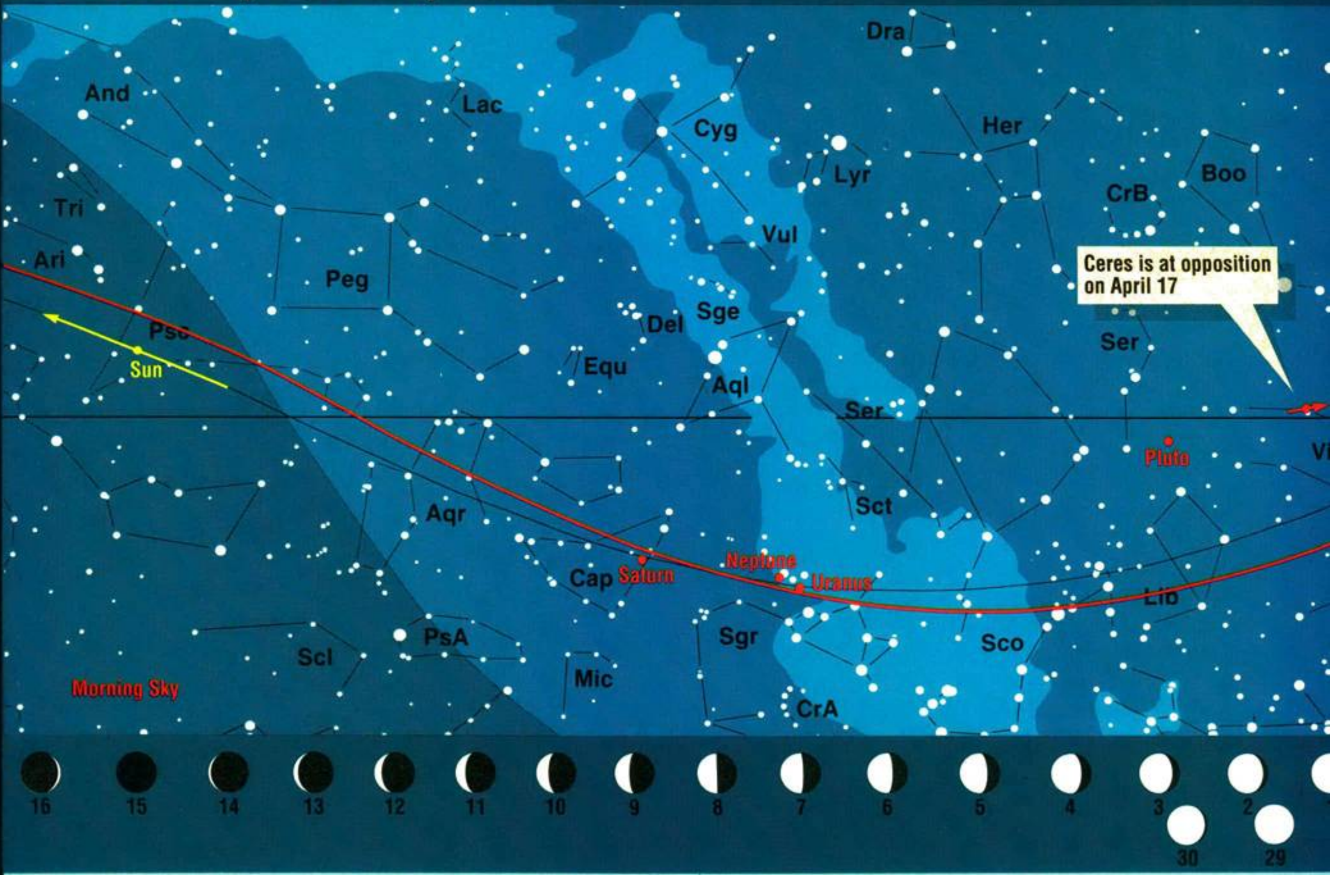
The Moon occults Antares early on the 4th for observers in the British Isles, central and southern Europe, the western U.S.S.R., and western Turkey. You should see Antares' green, 8th-magnitude companion remain visible for a few seconds after the primary has been occulted. On the 20th at about 0h UT (8 p. m. EDT, April 19), the Moon occults Mars, as seen from the South Pacific and the southwest of South America.

Saturn, Uranus, and Neptune keep a quiet vigil in the morning sky. Saturn's southerly declination places it high in the sky for observers in the Southern Hemisphere, but you can get good views late in morning twilight as Saturn crosses the meridian just before sunrise. Like Jupiter, Saturn is also at quadrature this month, so the shadow that the planet casts on the rings behind it will be particularly easy to see. Will there be any vestige of the Great White Spot remaining? Will other disturbances emerge? If you don't observe the ringed planet regularly, you'll never know. □



Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He leads the data management team on the Ulysses *mission, which is on its way to Jupiter and ultimately the Sun.*

The Solar System April 1991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Scl
Mic
CrA
Morning Sky
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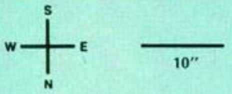
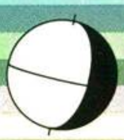
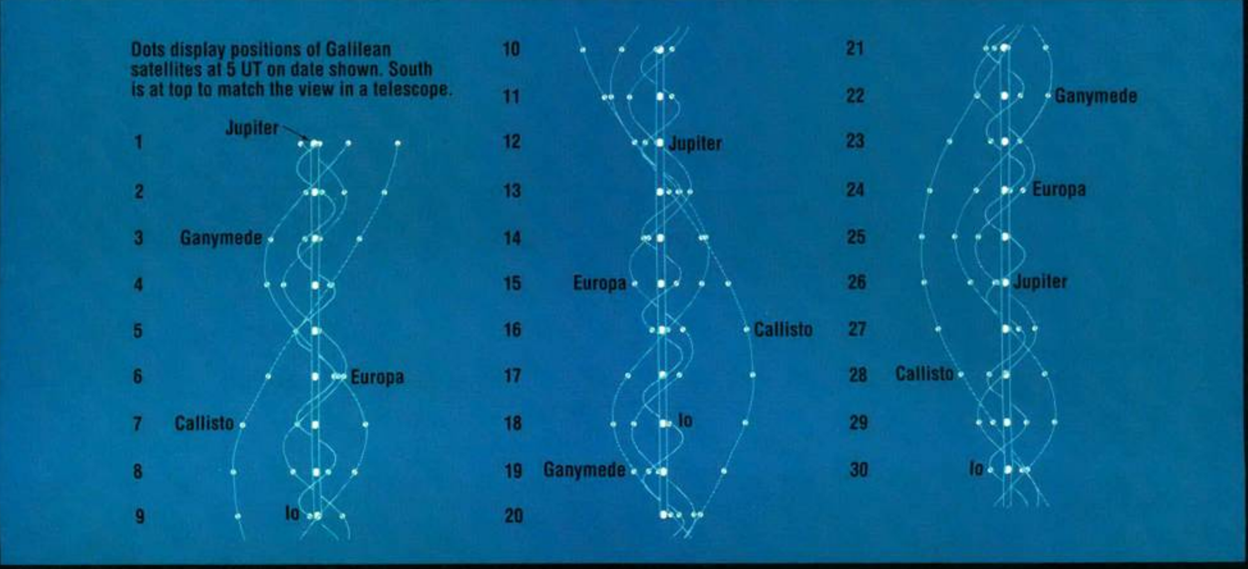
Ceres is at opposition on April 17



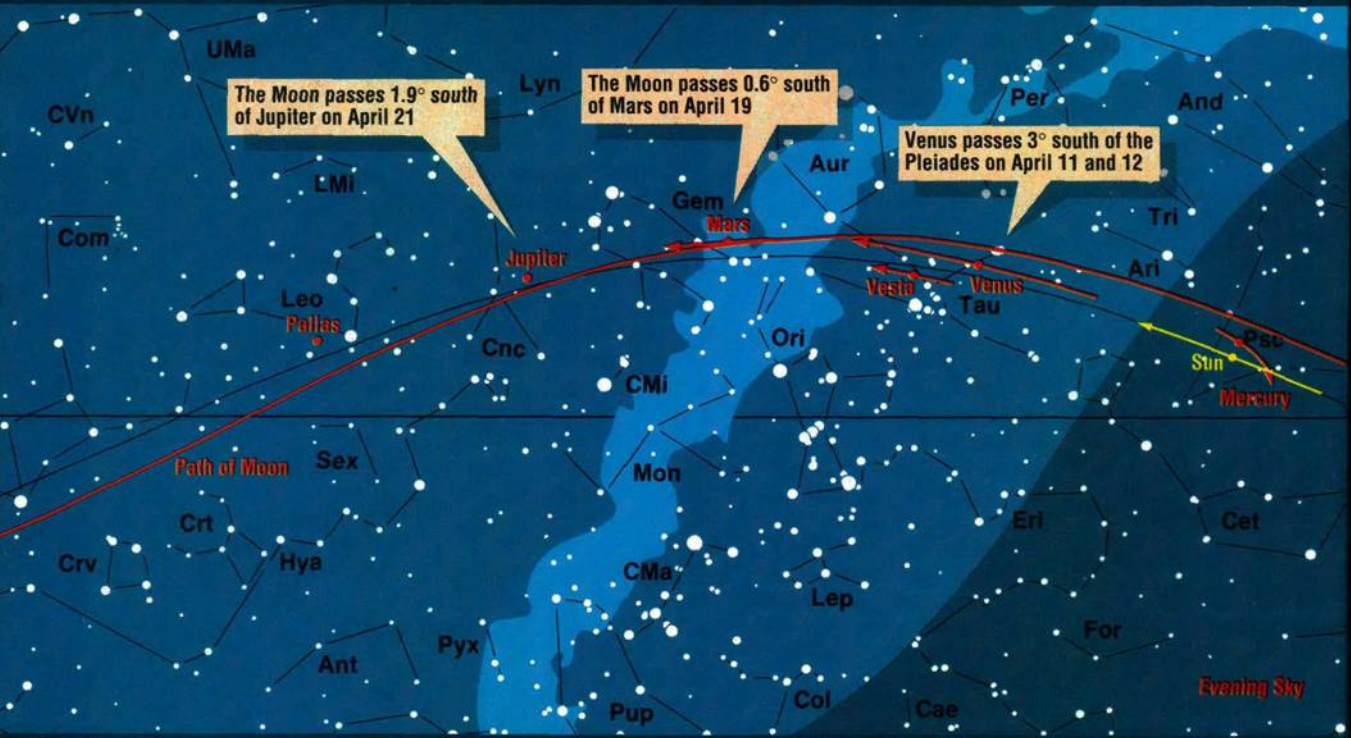


Planet	MERCURY	MERCURY	VENUS	MARS
Date	April 1	April 30	April 15	April 15
Magnitude	+0.8	+1.6	–4.0	+1.2
Angular Size	8.6″	10.4″	14.3″	5.6″
Illumination	26%	19%	76%	91%
Distance (AU) from Earth	0.783	0.648	1.163	1.659
Distance (AU) from Sun	0.347	0.466	0.718	1.651
Right Ascension (2000.0)	1h40.7m	1h09.9m	4h00.3m	6h29.0m
Declination (2000.0)	13°43′	5°28′	22°06′	25°06′

Jupiter's Moons



Dots display positions of Galilean satellites at 5 UT on date shown. South is at top to match the view in a telescope.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And
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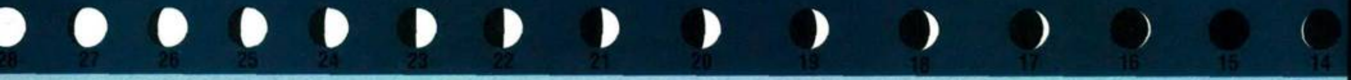
Tau
Ori
CMi
Psc
Sun
Mercury
Path of Moon
Sex
Mon
Crt
Crv
Hya
CMa
Lep
Eri
Cet
Pyx
Ant
For
Col
Pup
Cae
Evening Sky

The Moon passes 1.9° south of Jupiter on April 21

The Moon passes 0.6° south of Mars on April 19

Venus passes 3° south of the Pleiades on April 11 and 12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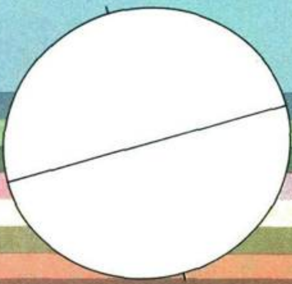
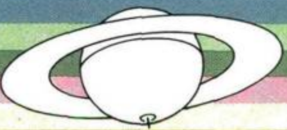
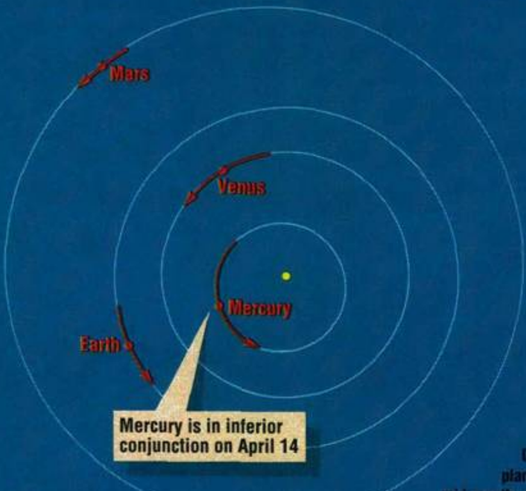


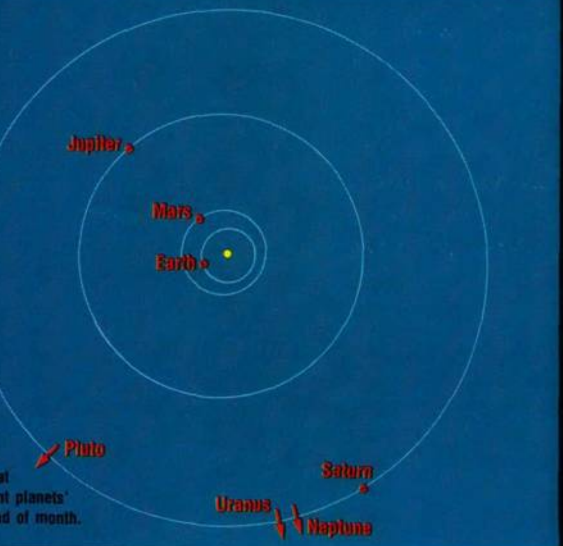


JUPITER	**SATURN**	**URANUS**	**NEPTUNE**	**PLUTO**
April 15	**April 15**	**April 15**	**April 15**	**April 15**
−2.2	+0.7	+5.7	+7.9	+13.7
38.9"	16.3"	3.6"	2.2"	0.1"
99%	100%	100%	100%	100%
5.059	10.128	19.252	30.048	28.792
5.316	9.977	19.463	30.200	29.671
8h26.2m	20h34.3m	19h00.7m	19h12.8m	15h26.0m
20°00'	−19°01'	−23°04'	−21°35'	−2°36'

The Planets in Their Orbits


Mars
Venus
Mercury
Earth

Mercury is in inferior conjunction on April 14


Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

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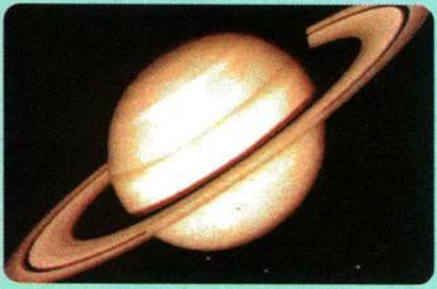

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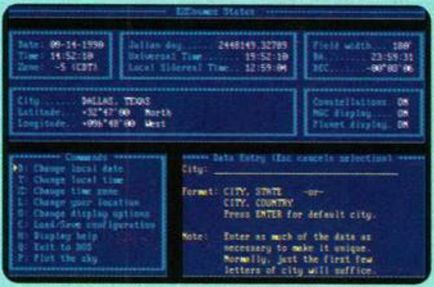

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EZCosmos Status

Date: 09-14-1990     Julian day....... 2448149.32789     Field width... 180°
Time: 14:52:10       Universal Time........ 19:52:10     RA........ 23:59:31
Zone:  -5 (CDT)      Local Sidereal Time... 12:59:04     DEC....... -00°00'06

City....... DALLAS, TEXAS                                Constellations. ON
Latitude... +32°47'00   North                            NGC display.... ON
Longitude.. +096°48'00  West                             Planet display. ON

Commands                         Data Entry (Esc cancels selection)
D: Change local date             City: ______________________
T: Change local time
Z: Change time zone              Format: CITY, STATE    -or-
L: Change your location                  CITY, COUNTRY
O: Change display options                Press ENTER for default city.
C: Load/Save configuration
H: Display help                  Note:   Enter as much of the data as
Q: Exit to DOS                           necessary to make it unique.
P: Plot the sky                          Normally, just the first few
                                         letters of city will suffice.
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The Trifid Nebula (M20) is just one of the fascinating full-color images.

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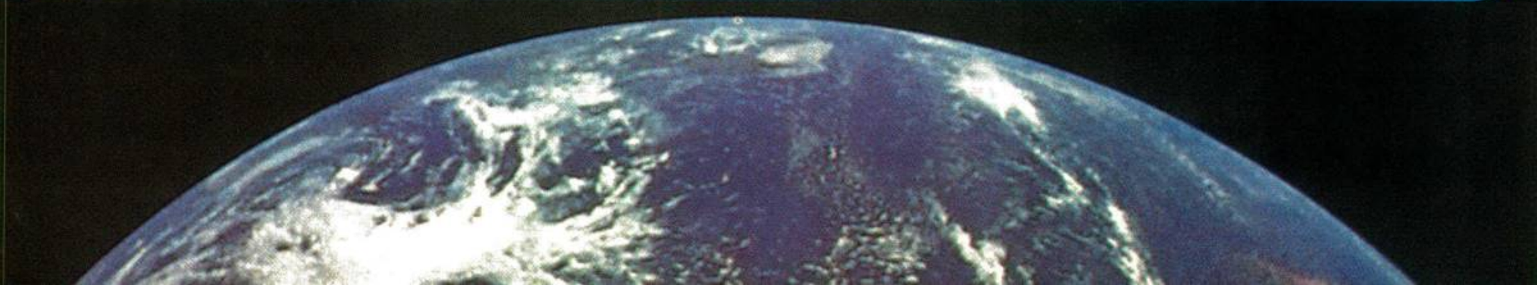


DESERT SHIELD ASTRONOMY

"As an Air Force pilot, I greatly treasure the views of the night sky I get from aircraft," says Captain Karl W. Kornchuk, of Presque Isle, Maine. When he was sent to take part in Operation Desert Shield last August, Kornchuk knew that he would be stationed in a classified location south of the equator. He immediately thought of the fabulous astronomical sights he could see while stationed at his desert air base.

"Until recently, all of my observing had been done from mid-northern latitudes," explains Kornchuk. "For the past two months, however, my temporary duty has given me a real astronomical treat. On August 12 the Perseids put on a fine show throughout the night. As I flew the plane I noticed a number of tremendously bright Perseids out of the corner of my eyes. Even during air refueling — which requires careful concentration — I saw a number of bright meteors. Later, just before sunrise, Jupiter and Venus were also 'flying in close formation' — they formed a spectacular sight!

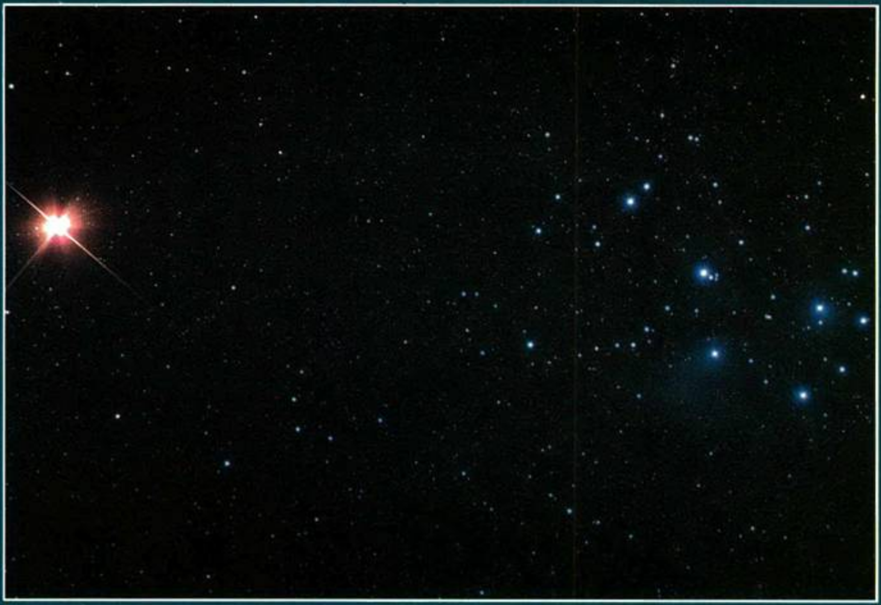
"Desert Shield astronomy hasn't been limited to the solar system or to the air, however," says Kornchuk. "At my observing location on the ground, I set out the following evening armed with a Southern Hemisphere star chart. I got my first glimpse of the Southern Cross along with brilliant Rigel Kentaurus and Agena — what a bright, compact group of stars! I found the more familiar constellations of the zodiac high overhead, and it gave me a funny feeling to look directly up to see Saturn resting in Sagittarius. I stepped outside again shortly before sunrise and there was Orion, 'upside down,' along with the brilliant stars Sirius and Canopus, the latter forever hidden below the horizon from my home in northern Maine.

"A few weeks later I had one of the greatest thrills of my stay," says Kornchuk. "I observed the Large and Small Magellanic Clouds from 37,000 feet, again just before sunrise. Shortly thereafter Mars struck me as astonishingly bright, outshining nearby Aldebaran. The elusive zodiacal light rose like a pillar in an otherwise pitch black, moonless sky over the Indian Ocean.

"The night sky seen from my Desert Shield station is truly unreal. Typically the sky is so black it appears like diamonds and brilliant gems spilled over a velvety black background. Flying the plane provides a high-altitude observing platform that is light-years ahead of my observing from Maine.

"Whatever the outcome of my participation in Operation Desert Shield, I'll always remember the incredible views I've had and the unusual opportunity to have them." — *David J. Eicher.* □

A SEEMINGLY ENORMOUS MOON rises over the Robert Moses Bridge in New York. Photo by Larry Landolfi.



MOON OVER LAKE SUPERIOR

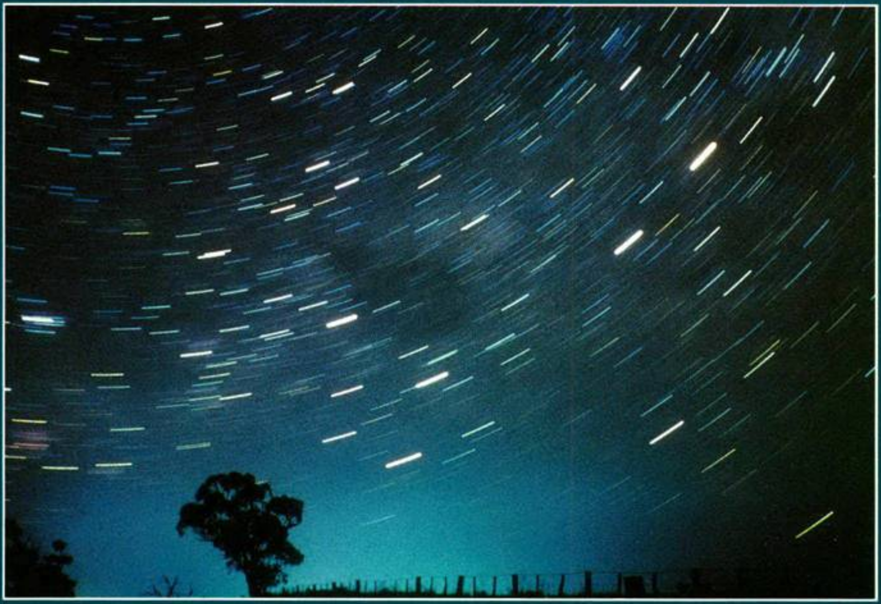
Bob King's multiple-exposure photograph of the Moon rising over Lake Superior near Duluth, Minnesota (opposite page), nets this month's $100 "Best Astrophoto" award.

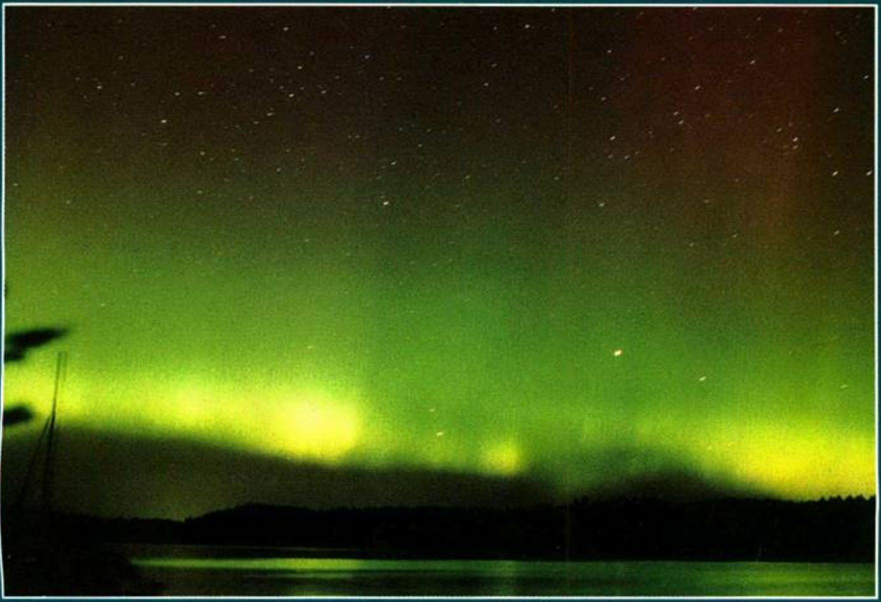
Recent solar system events included the close passage of Mars by the Pleiades star cluster. On December 9, 1990, Michael Stecker of Los Angeles recorded the two objects separated by just under 5° (above left).

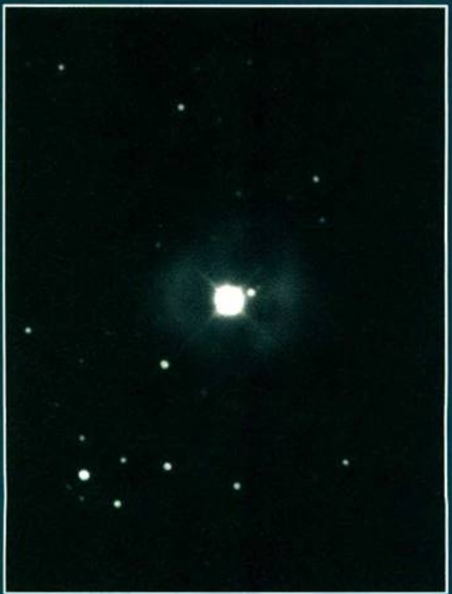
Recent photography by readers also revealed stars trailing around the south celestial pole, as recorded by C. J. Dunmill of Dimboola, Australia (left center). Dunmill used a 50mm f/2.8 lens, Fujichrome 400 film, and a 10-minute exposure.

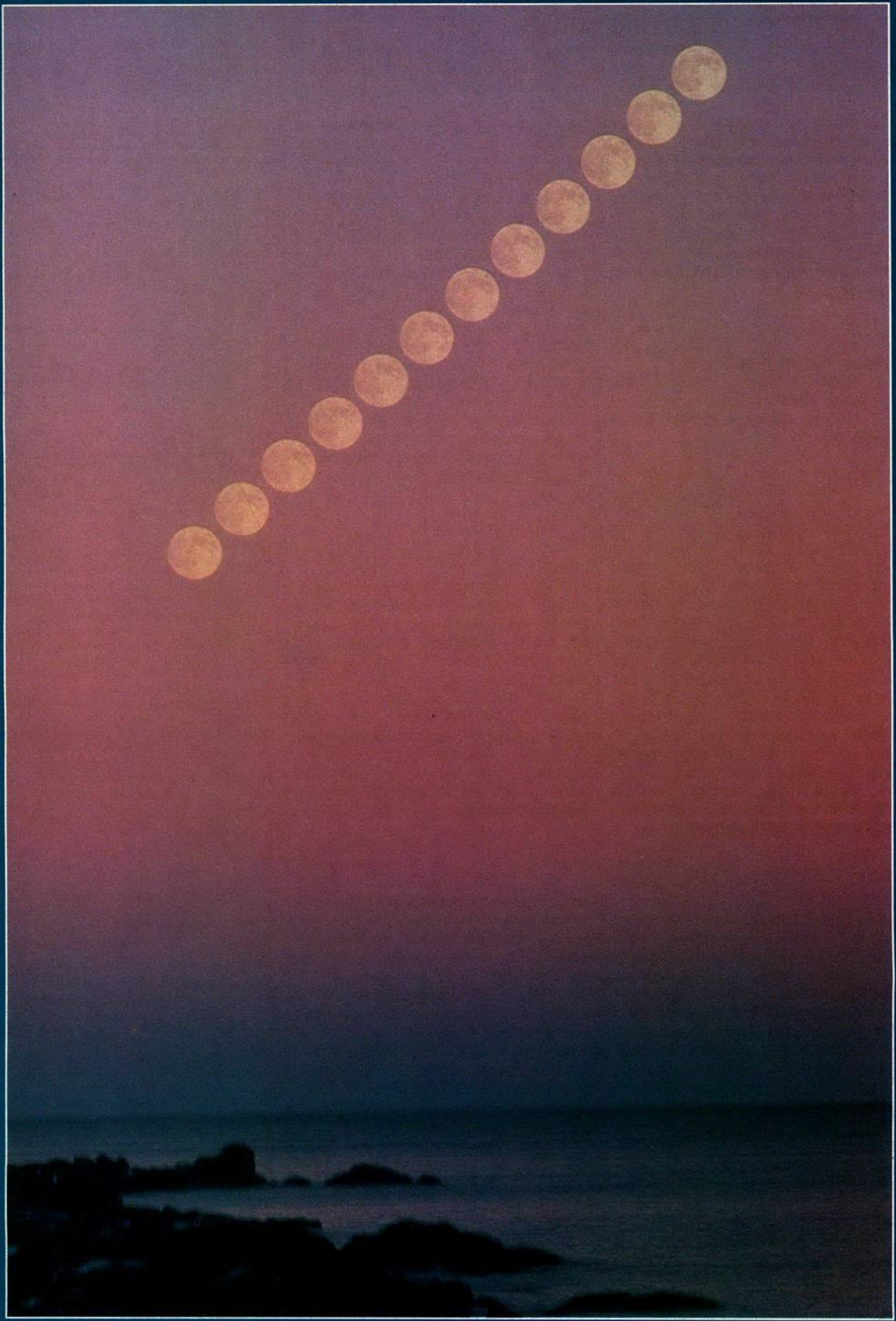
Last August Brian Fell recorded a spectacular auroral display over Niagara Falls, Ontario (bottom left). Fell used a 50mm f/2.8 lens, Ektar 1000 film, and a 1-minute exposure.

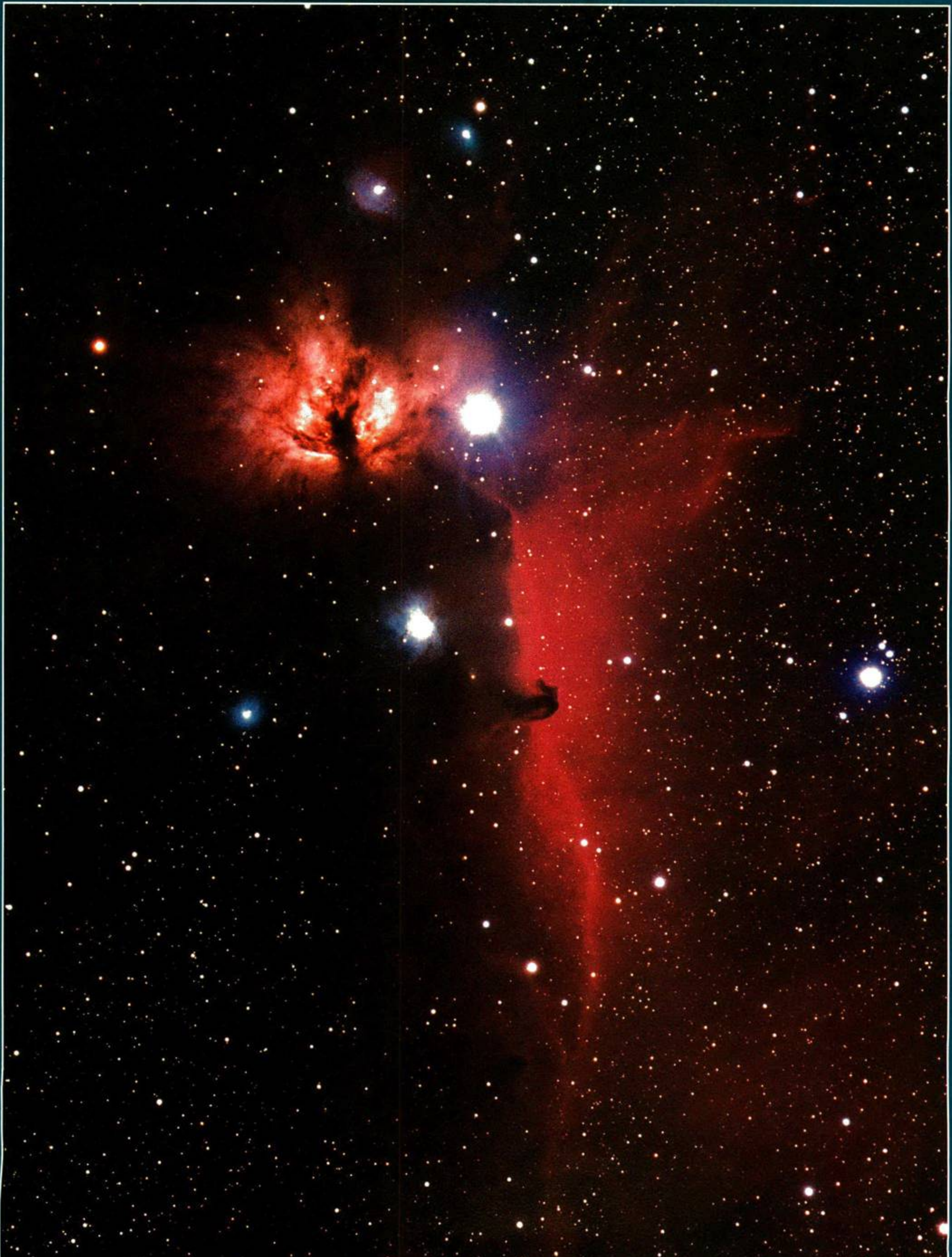
Equipped with a 14.5-inch Cassegrain at f/8, Kim Zussman of Thousand Oaks, California, captured the subtle nebular shell of planetary nebula NGC 1514 (below). Zussman used hypered Tech Pan film for the 110-minute exposure.











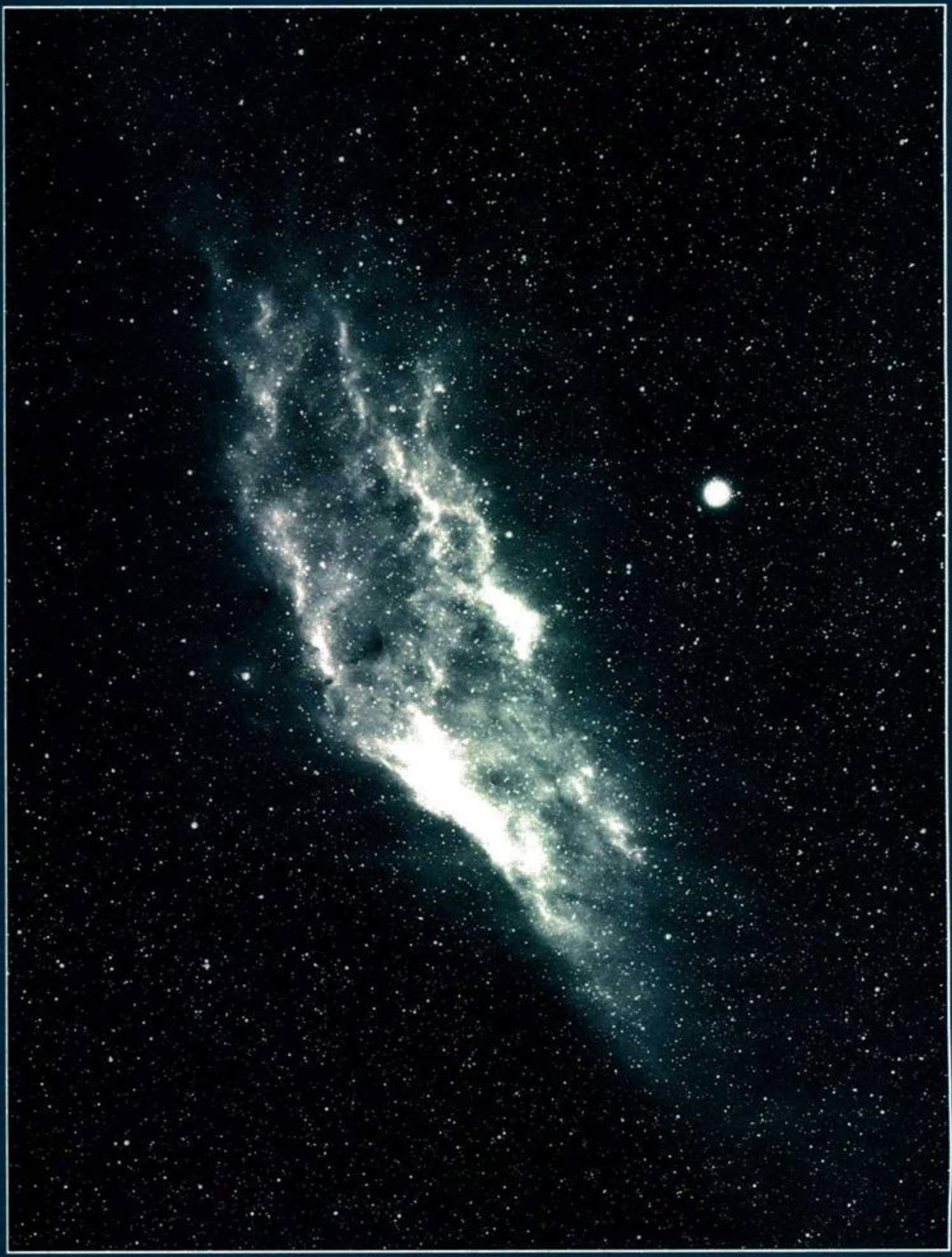
THE SPLENDOR OF ORION'S BELT

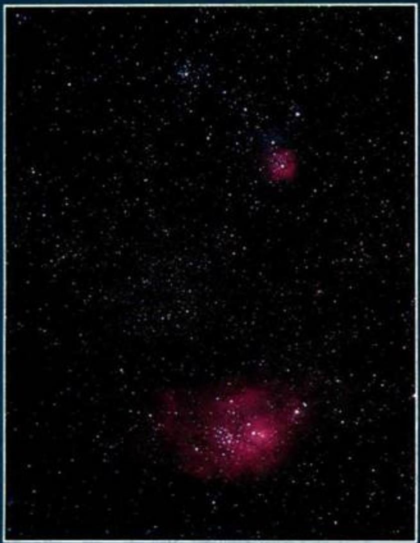
Few regions of the sky contain a greater concentration of stars and gas than Orion's Belt, and few amateur photographs of the area rival that taken by Tony Hallas and Daphne Mount (opposite page). To take the photo, which contains the Horsehead Nebula, emission nebula NGC 2024, reflection nebula NGC 2023, and the bright star Alnitak, Hallas and Mount used a 6-inch EDF refractor and hypered Fujichrome HG 400 film.

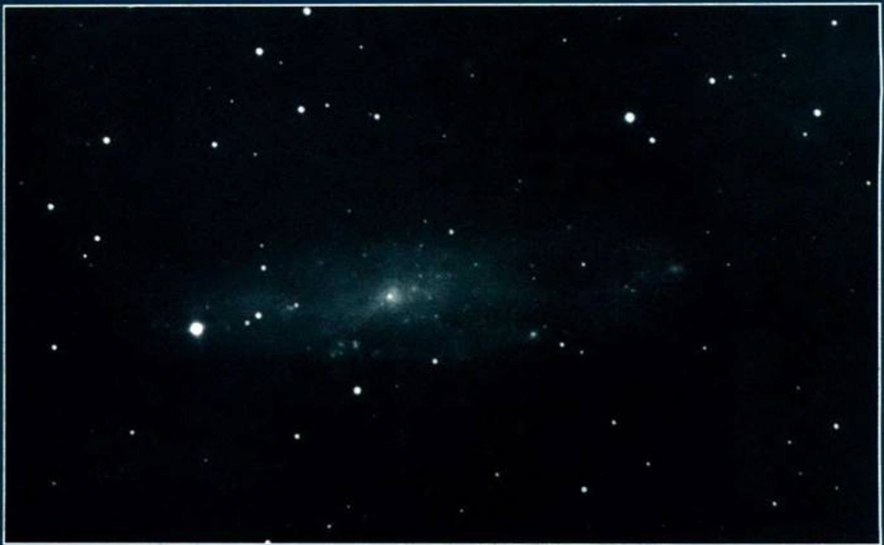
One of the largest emission nebulae in the winter sky is the California Nebula in Perseus (right). To capture the intricate detail of the nebula, Chuck Vaughn of Fremont, California, used a 500mm f/4 lens, hypered Tech Pan film, an Hα filter, and a 110-minute exposure.

An obscure treasure of the autumn sky, galaxy NGC 247 in Sculptor displays a lovely loose, knotty arm structure. Kim Zussman recorded its appearance with a 14.5-inch f/8 Cassegrain, hypered Tech Pan film, and a 115-minute exposure (below right).

Summer's premier pair of nebulae is composed of the Lagoon Nebula and the Trifid Nebula. Bill Hood's photo shows the objects' prominent red and blue colors. It was made with a 400mm f/8 lens, hypered Fujichrome 400 film, and a 20-minute exposure (below).







How to Photograph the Eclipse

Even if you've never taken an astrophoto in your life, you can come away from July's eclipse of the Sun with a roll of perfect photos, every one a treasured souvenir of a memorable event.

by Alan Dyer

An image of a total eclipse of the Sun is one of the most dramatic photographs you can ever take. You'll value it for a lifetime. Each glance at your framed portrait of the eclipsed Sun will remind you of the indescribable mix of emotions you felt as you were engulfed in the Moon's shadow.

On July 11, 1991, you'll have the opportunity to witness and photograph a total solar eclipse, but only if you are in the path of totality. This narrow band will extend across the Pacific Ocean and neatly encompass the Big Island of Hawaii. The path will also touch the southern tip of the Mexican Baja Peninsula and sweeps across mainland Mexico. Though the path of totality will extend over parts of Central America and northern South America, good weather prospects and tourist facilities make Hawaii, Baja, and the west coast of mainland Mexico the prime viewing sites. (For more information about the circumstances of July's eclipse, see "Journey Into Darkness," in the July 1990 ASTRONOMY.)

The highlight of a total eclipse, the thing you travel thousands of miles to see, is the outer atmosphere of the Sun, its pearly corona. This delicately structured glow is visible to the unaided eye only during an eclipse. Capturing an image of this corona, and of the other eclipse phenomena, might at first seem like a complex task involving high-priced equipment and skills beyond those of most photographers. Surprise! Photographing a solar eclipse is actually one of the easiest types of celestial photography. Sure, you can get sophisticated if you want to. You can haul thousands of dollars worth of equipment with you to the shadow path. Some of it might actually work.

However, my advice is to keep it simple. With no more than a camera on a tripod you can still produce dramatic results. The secret to good eclipse photos is not elaborate equipment but good planning. Although the eclipse is still three months away, it's not too early to start making those plans.

Eclipse Photos the Easy Way

When planning your dream photo, chances are your first thought is to use a telescope or as long a telephoto lens as you can lug with you. But you can travel light and still get great photos. This is particularly important for those traveling by air who will find it difficult to take heavy, bulky equipment with them.

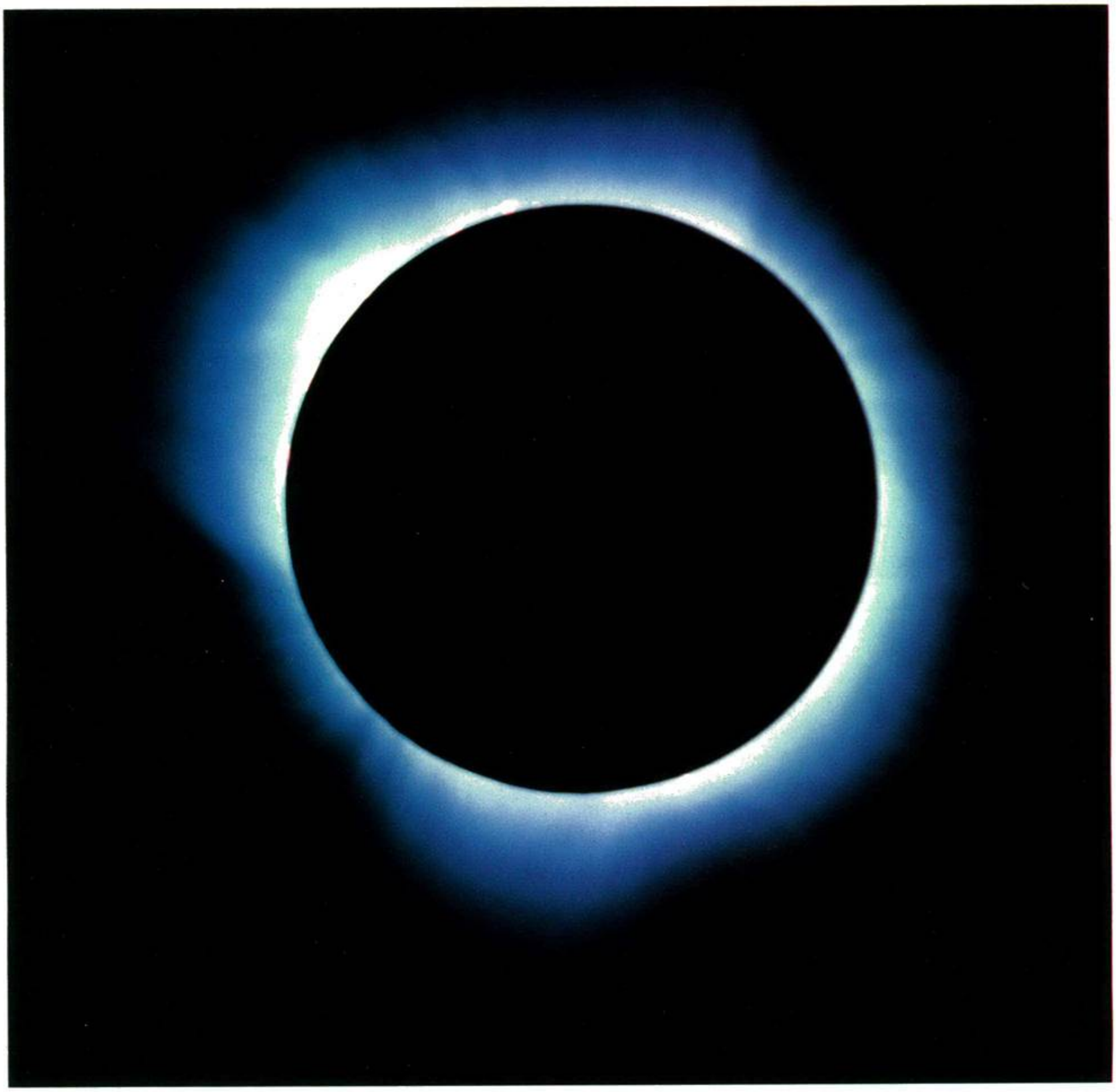
GOOD ECLIPSE PHOTOS require fine-grained film, precise focusing, and a steady camera.

You can get an eclipse photo to be proud of with no more than a camera equipped with a 50mm lens and a sturdy tripod. With a 50mm lens the Sun's disk will be small, only 0.5mm across on the frame. What creates the pictorial impact is creative composition. The trick is to include a scenic landscape (there's no shortage of those on the Big Island of Hawaii), a palm-tree-lined beach, an ocean vista — something to set the scene. The "hole-in-the-sky" impression created by a total eclipse turns even the most mundane terrestrial setting into a surrealistic image.

This type of scenic eclipse photo will work best from Hawaii. From there the eclipse occurs shortly after sunrise, at 7:30 a.m. local time. At mid-eclipse the Sun will be about 22° above the northeast horizon (at an azimuth of 73°, with 0° being due north and 90° being due east). The field of view of a 50mm lens (the normal lens for a 35mm format camera) is about 27° high by 40° wide. This is just enough to include the eclipsed Sun at the top of the frame and the horizon at the bottom. Turning the camera vertically might be better, depending on how much extra area you want to include above the Sun and below the horizon. If you use a 35mm wide-angle lens (with a field of 38° by 54°) you can keep the photo horizontal and still frame the scene with a generous amount of space.

The final selection of focal lengths will depend on your site and photo composition. The main challenge will not be the technical aspects of taking the photo but the logistics of finding a photogenic location you'll be able to get to on eclipse morning. Remember, tens of thousands of eclipse enthusiasts will also be jamming Hawaii's narrow roads on July 11, and some choice locations, such as the roads up Mauna Kea and Mauna Loa, will be closed on eclipse day.

From any of the sites along the eclipse path in Mexico the Sun-over-the-horizon photo will not be possible. From the Mexican sites, including Baja, the eclipse occurs near midday, with the Sun nearly overhead. To capture the Sun *and* the horizon you'll need a fisheye lens. A lens with a circular field of view of



THE ECLIPSED SUN makes a dramatic photograph. Jacques Guertin used Ektachrome 64 film to capture the June 1983 eclipse from Java. He used a Quantum 6 Maksutov telescope at f/19 and a 1/2-second exposure.

180° aimed straight up will put the Sun in the center of the photo framed by the eerie orange 360° twilight that occurs only during total eclipses.

With a longer lens in Mexico you will get nothing but the Sun and sky in your picture. However, you can use a 35mm wide-angle lens to good effect. Mercury, Venus, Mars, and Jupiter will be 20° to 40° east of the Sun. A 5- to 10-second exposure will overexpose the solar corona but will bring out the bright stars and planets surrounding the eclipsed Sun.

A 24mm lens (with a field of 53° by 74°) will also just take in Sirius and the stars of Orion southwest of the Sun. This type of wide-angle photo should work well during July's eclipse since from Mexico totality lasts a full 7 minutes. The longer the eclipse, the darker it usually becomes at mid-totality.

Telephoto Lenses and Other Equipment

To get close-up images of just the eclipsed Sun, use a long telephoto lens. With a 135mm lens the Sun will be only a millimeter or so across on the film. A 300mm to 600mm lens is far better. (To determine the Sun's image size with your lens, divide the lens focal length in millimeters by 110.) If you don't have such a long lens, a 2x or 3x teleconverter will help, though cheap teleconverters degrade image sharpness.

Another essential piece of equipment is a rock-solid tripod. With a long, heavy lens on a lightweight tripod, you risk fuzzy photos from the tripod's shaking or, worse, ruined photos from the tripod's collapsing or sagging at a critical moment. Even with a heavy tripod, use a cable release to trigger the shutter so that vibration is minimized.

If you are photographing from a ship, a telephoto lens and a tripod is probably the best setup. Compared to a telescope, the wider field and lower magnification of a moderate telephoto will be more forgiving of any image motion imparted by the rolling of the ship. Even so, you'll have to keep exposures short.

SELECTING A FOCAL LENGTH is your most important photo-planning decision. On July 21, 1990, Reginald Poole used a 200mm telephoto to capture a partially eclipsed setting Sun and the surrounding landscape.

ON BOARD A SHIP in November 1984, Jim Manning used a 28mm wide-angle lens to capture the eclipsed Sun and the horizon twilight glow. Rolling of the ship caused him to switch at the last minute to ISO 400 film so he could use faster shutter speeds, a common problem for shipboard photographers.

Restrict your shots to those moments when the ship stops moving.

Another accessory you'll find helpful in Mexico is a right-angle attachment for your camera viewfinder. Without it, you'll find it a pain in the neck to look through the camera with it aimed straight up.

Using a Telescope

For detailed shots of the Sun's corona and fiery red prominences, you'll need a focal length of 750mm to 2000mm. This means removing the lens from your camera and using a camera adapter to attach the lensless body to the focuser of a telescope. You don't need a large telescope; a portable 3- or 4-inch scope with a focal length of about 1000mm is perfect.

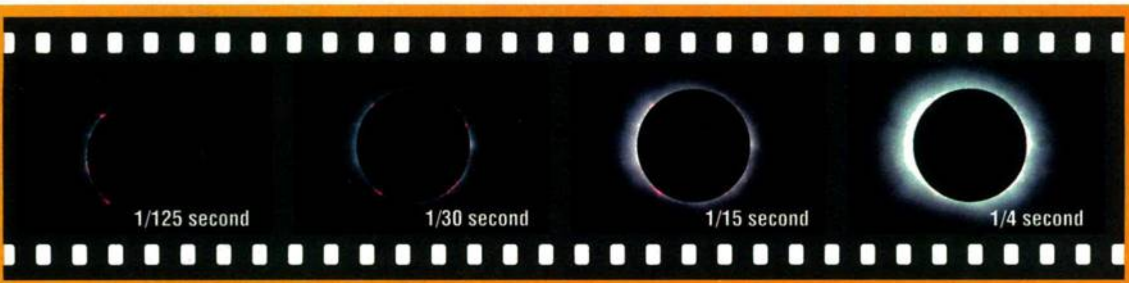
Shooting at high power through a telescope introduces three possible sources of trouble: blurring from poor focus, blurring from image motion, and poor framing because the Sun drifted out of the frame during the few minutes of totality.

Unlike telephoto lenses which you simply focus at infinity, a telescope requires careful focusing. You can focus on the filtered Sun before totality. But for the best results you should focus on the prominences or limb of the Moon *after* totality begins and you have removed your solar filter. Poor focus is the biggest flaw in many of the telescopic eclipse photos we at ASTRONOMY receive after every eclipse. Take the time to focus. Fewer photos is a small price to pay for good photos.

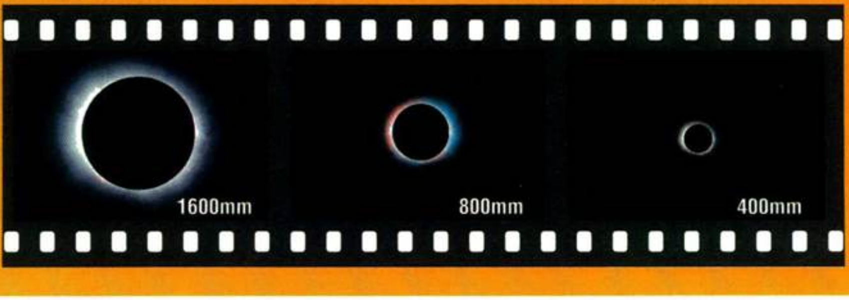
Also be careful not to bump or jar the camera or telescope. Crank the film advance lever slowly. If you can, lock up your camera mirror. Use the self-timer instead of a cable release or, at the very least, be careful to let all vibration die down before firing the shutter. And don't set up where lots of people will be jumping up and down during the eclipse. With long focal lengths, vibration from any source can blur the image.

With long focal lengths you also run the risk of having the image blur simply from the Sun and Moon's natural motion. For example, with a 750mm focal length telescope and exposures longer than about 1 second the image will trail slightly. This shouldn't be a big problem since most eclipse exposures, even with slow film, are shorter than that. However, with telescopic focal lengths you should consider using an equatorial mount and a clock drive. The drive will track the Sun and ensure sharper photos.

A clock drive also keeps the Sun



ECLIPSE EXPOSURES ARE VERY FORGIVING — shorter exposures are best for the bright prominences, while successively longer exposures reveal more of the corona. This series of the February 1979 eclipse was taken on Kodachrome 64 film using a Questar 3.5 Maksutov telescope at f/16. Photos by Alan Dyer.



THE LONGER THE LENS the larger the image. For detailed close-up photos you should use at least a 300mm to 400mm lens.

centered in the frame. During the 7 minutes of totality, the Earth's rotation will carry the eclipsed Sun about 3½ solar diameters, or 1.75°, across the sky. Many a photographer has happily fired away during an eclipse only to find out at the end of the sequence that the Sun was halfway out of the frame during most of the eclipse. A clock drive avoids that, *if* you have the mount aligned to the north celestial pole. You may not be able to set up the night before to do a proper alignment, but you should at least have the polar axis aimed north and at the right altitude. You'll be observing the total eclipse from a latitude of about 20° North. Be sure your mount can polar align at that low latitude. Not all can.

Selecting the Best Film and Exposure

A major mistake people make in eclipse photography is to use a fast, grainy film. It's natural to assume that since the Sun will disappear and the sky will get dark you need a fast film, just as you would if you were taking photos of stars at night. Not so. The corona surrounding the eclipsed Sun is surprisingly bright. Even scenic photos of the horizon twilight are best on a relatively slow film. A slow-speed, fine-grained film will give you a sharper image that will withstand enlargement.

The best film for just about every type of eclipse photo is an ISO (or ASA) 25 to 125 film. You can use either a print film (like Kodak Ektar 25 or 125) or a slide film (I prefer Kodachrome 64). Either type of film will give good results. However, something to keep in mind with prints is that the delicate solar corona exhibits a wide range of brightness. Retaining this dynamic range in a print can be a challenge for even the most experienced darkroom "dodger and burner." Your local quick-print lab certainly won't succeed.

Another misconception people have about eclipses is that unless you get the exposure just right the photos will be ruined. Relax. There is no single correct exposure. Shorter ones reveal just the brilliant red prominences and inner corona. Successively longer exposures show more of the corona. Even in Hawaii, where the eclipse lasts 4 minutes, you have time to take a wide range of exposures, and chances are most of them will be usable.

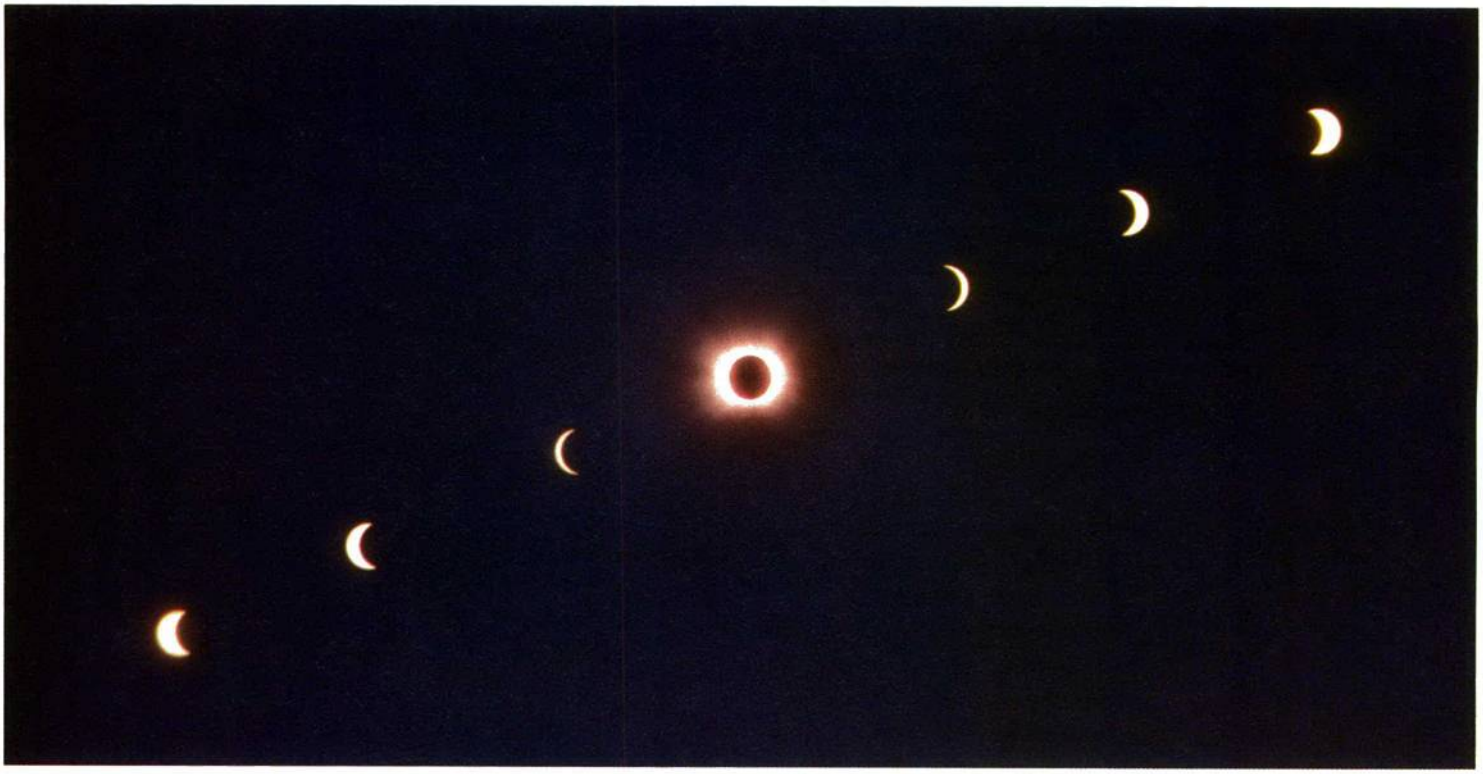
For example, for any of the wide-angle or scenic photos, exposures in the range of 1/4 to 12 seconds at f/2.8 to f/4 will work well. Darker frames may record the scene as you remember it, while lighter frames may show landscape details and faint stars that you don't remember seeing but that add to the impact of the photo.

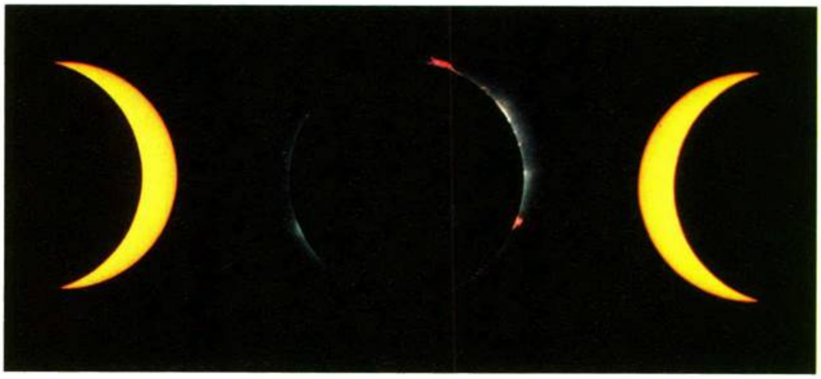
For telephoto lens shots of the totally eclipsed Sun, use exposures from 1/1000 to 1/8-second at f/4 to f/5.6. At the onset of totality, the last sliver of sunlight can form discontinuous spots of light along the edge of the Moon called Baily's beads. This is followed by the fleeting but glorious "diamond ring" as one last burst of sunlight shines through a lunar valley. You have only a few seconds to capture these effects. Use shutter speeds of 1/1000 to 1/125 of a second.

Over the next minute or so, stay in the short exposure range of 1/500 to 1/30 second. This will capture the brilliant red prominences. Because of the large size of the Moon's disk at this eclipse, prominences will be visible only at the start and end of the total phase. At mid-eclipse the Moon's disk should cover most of the prominences unless there is a gigantic one jutting out from the limb of the Sun.

During the middle portion of the eclipse, lengthen the exposures step-by-step to a maximum of about 1/8 to 1 second. This sequence will capture the full extent of the corona, from the bright inner corona to its faint outermost portions.

Then do something you may not have planned for — STOP AND ENJOY THE ECLIPSE. Get out a pair of binoculars and just look. You won't regret it. You've come a long way and you may never get this chance again. The image of the totally eclipsed Sun through a pair of binoculars will record in your memory with more lasting value than any photograph.





MULTIPLE-EXPOSURE PHOTOS leave no room for error. Above, William Sterne recorded the February 1979 eclipse using 1/400-second exposures taken 10 minutes apart on medium format 2 1/4 x 3 1/4 Vericolor II film. A 3-second exposure with the solar filter removed captured the total phase.

A TRIPLE EXPOSURE captured the February 1979 eclipse. Jim Rouse used a Celestron 5-inch telescope, Kodachrome 64 film, a Microline solar filter for the partial phases, and 1/125-second exposures for all three images.

At this point you may become so enthralled with the view that your well-planned sequence simply goes out the window. You may not get any photographs after this. Don't worry. What you've got so far will do just fine. However, if you want more eclipse photos, then during the last half of the eclipse you should step back down the shutter speed range, returning to 1/125 to 1/1000 second or so just before the Sun reappears. This will capture the prominences on the other limb of the Sun and give you another chance at the diamond ring, which, chances are, happened so quickly at the start that you weren't ready for it.

For photos through your telescope, the sequence is exactly the same. To determine exposures you'll need to know your scope's f/ratio. This number may be marked on the instrument. If it isn't, simply divide the focal length by the diameter of the lens or mirror (measured in the same units as the focal length). For example, a 3-inch telescope (80mm aperture) with a focal length of 1,200mm is an f/15 instrument (1200/80).

For most telescopes, the exposures should range from 1/500 to 1/2 second at f/10 or f/11. Faster scopes (f/4 to f/8) will require shorter exposure times, while slower scopes (f/16 or so) will require longer exposures. See the table on the next page for details.

Filters and the Partial Eclipse

You do not need a solar filter for the total phase of the eclipse. For those brief minutes during totality, the eclipsed Sun is perfectly safe to look at and aim an unfiltered camera at. You *do* need a filter for the partial phases. The safest filters are the metal-on-glass or the mylar types that fit over the front of the lens or telescope aperture. These are available from Celestron, Roger W. Tuthill, Inc., and Thousand Oaks Optical.

For photography you can also use a #12 to #14 welder's filter. (Don't use anything lower in density than a #12.) These are not optically flat, but will provide acceptable images when securely taped over the front of a short telephoto lens (100 to 400mm). Welder's filters are green, so the color of the Sun is not the most pleasing, but the price is right — welder's filters are about $2 each.

Do not use photographic neutral-density filters, crossed polarizers, or stacked layers of film. These may reduce the levels of visible light, but only approved astronomical solar filters or welding filters block all of the *invisible* ultraviolet and infrared light that can damage your retina.

Exposures for the partially eclipsed Sun depend on your filter, but will likely fall in the range of 1/125-second at f/8 with ISO 64 film. Since the Sun is the same brightness when it's not eclipsed, you can take test shots well in advance of eclipse day to settle on film and exposure times. On the day itself, use your "correct" exposure for all the partial phases but bracket each exposure over and under by at least one f/stop or one shutter speed increment.

Eclipse Exposures

At...	f/4	f/5.6	f/8	f/11	f/16
		...with ISO 64 film*, use...			
Partial Phases	1/500	1/250	1/125	1/60	1/30
Diamond Ring	1/2000	1/1000	1/500	1/250	1/125
Prominences	1/1000	1/500	1/250	1/125	1/60
Inner Corona	1/250	1/125	1/60	1/30	1/15
Outer Corona	1/15	1/8	1/4	1/2	1 sec

* For ISO 25 films, lengthen all recommended exposures by a factor of 2 (1/500 becomes 1/250). For ISO 125 films, shorten all exposures by a factor of 2 (1/500 becomes 1/1000).

For shots of the partially eclipsed Sun, use a solar filter over the aperture of the telescope or lens. The exposure will depend on the density of the filter.

Getting Creative

Most photographers are happy to record the partial phases and the total phase on separate frames. But with planning and a camera capable of multiple exposures, it's possible to record the entire sequence of a solar eclipse on one frame. This will work for either the partial-only eclipse seen from most of North America or for the total eclipse.

During the partial phases, keep the filter on for every shot. Remove it only for a single image of the totally eclipsed Sun. Make exposures precisely spaced once every 10 minutes. Do not move the camera between exposures — the idea is to let the motion of the sky carry the Sun and Moon across the picture.

From Hawaii the partial phase begins with the Sun 8° high and ends with the Sun 36° high. You'll need to use a 35mm wide-angle lens to frame the entire sequence on a horizontal frame. From Mexico, the Sun will move across an arc of 45° during the 3-hour eclipse, again requiring a 35mm lens to neatly contain the whole path. The real trick is getting the Sun where you want it on the frame at mid-eclipse. If you go to your site 24 hours before the start of the eclipse and note the position of the Sun, you should be able to reposition the camera accurately the next day.

If you are outside the path of totality and are photographing the partial-only eclipse, you could end the sequence with an unfiltered exposure of the whole scene. This will place the multiple Suns in a normal daylit sky. Wait until after the Sun moves out of the frame before adding this final touch.

Multiple-exposure photos are technical challenges and require concentration amid the excitement. The danger is that if you make one error in exposure or timing or if the camera gets bumped, the photo will be flawed. All of your eclipse eggs are in one basket.

Tips for Totality

The main reason people ruin their once-in-a-lifetime shots of an eclipse is that they attempt to do too much. Some people set up a battery of cameras and telescopes, each assigned to capture a particular aspect of the eclipse. This sounds good in theory, but during the excitement of the moment, it's easy to get flustered and make mistakes. The best eclipse tip is one I stated at the outset — keep it simple. Unless you are an experienced eclipse-chaser, I suggest you choose one type of photo and take care to do it right.

Here are some other tips that veteran eclipse-chasers have learned, often the hard way:

√ Test any new equipment long before the eclipse. A few minutes before totality is no time to find out that your new camera adapter doesn't fit.

√ If you are taking a telescope, be sure it will work at your destination's latitude when pointed where the Sun will be. Does the tube hit the tripod legs? Can you reach the camera and telescope controls easily? Is the scope still balanced?

√ When aimed straight up will the weight of your camera cause the focus of your telescope to slip? Will your zoom lens zoom when you don't want it to?

√ Be sure you can remove the solar filter at totality without jarring the camera.

√ Load a fresh roll of film at least 10 to 15 minutes before totality. Don't wait until the last minute — a lot will happen just before totality begins. And don't try to change rolls during totality. If you must have more than 36 pictures, use a second camera body. Motor drives and bulk-magazine film backs add weight, vibration, and complexity.

√ This may be hard to remember in all the excitement but if the air is very dry, advance and rewind the film slowly. Otherwise static electricity sparks could leap across the film.

√ If you are taking a multiple-exposure photo, cap the lens between each exposure to protect the innards of the camera from the Sun.

√ Take extra batteries. Most cameras today rely on them for powering the shutter. A pair of $1.98 batteries could be the weak link.

√ For insurance, take a spare camera and a kit of jeweler's screwdrivers to tighten those tiny screws on cameras and lenses that come loose at the most inopportune moments.

√ Take a flashlight. Remember, it's going to get dark. Very dark.

√ If you are flying, have film hand inspected at the x-ray machine. If you are driving, keep your film cool and dry before and after the eclipse.

√ Instruct the photo processer to return your film *uncut*. The last thing you want is a series of otherwise perfect images sliced down the middle by a careless lab technician.

√ Avoid taking telescopes and high-tech accessories that require AC power. There may not be an outlet handy in the deserts of the Baja. And don't even think of taking a generator for AC power. During a total eclipse people usually like to hear their own gasps of astonishment against the eerie silence. They will not want to listen to the roar of a generator.

√ Finally, practice, practice, practice. Choose your style of photo, get familiar with your equipment, and rehearse the steps over and over again, in the dark!

If all goes well on July 11, you should end up with photographs you'll show with pride for years to come. If you do, consider sending us duplicates of your results. ASTRONOMY will be collecting photos for a roundup in a post-eclipse issue and would love to see one of your treasured images among them. □

THE LIVES OF TWO BRIGHT PLANETS

During the last months of 1990 Mars and Jupiter prominently showed their stuff in the eyepieces of telescopes both large and small.

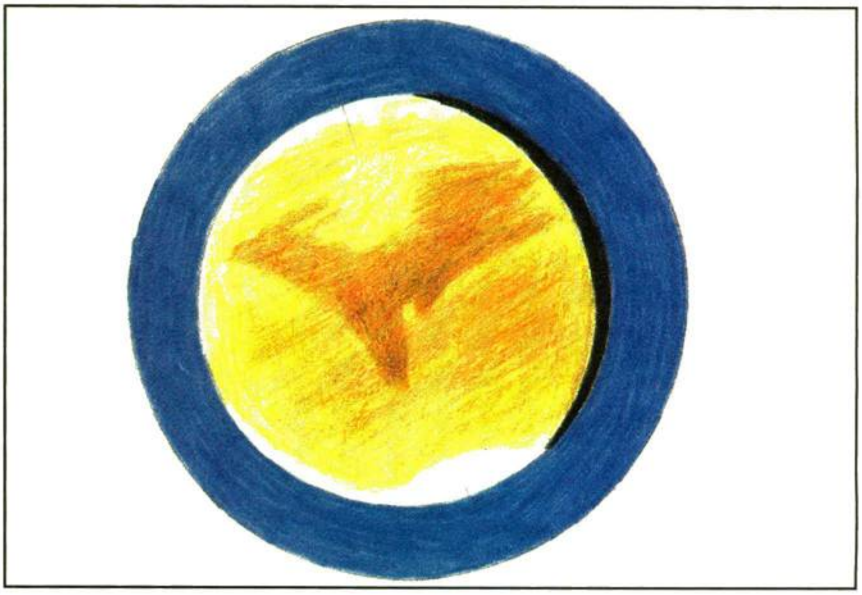
by David J. Eicher

It was an innocent enough night, at least on the surface. I went outside at 4:00 a.m., looked skyward, and spied a couple of old friends. It was August, and I was pleased to see Mars and Jupiter glowing with confidence in the morning sky that loomed above me. Mars shone like a beacon at magnitude –0.2, hovering in the western reaches of Taurus.

It was a rather unspectacular beginning to what would be a banner year in the lives of two bright planets. Mars reached opposition and its dark surface was observed by thousands. Jupiter tempted skywatchers with superb visibility and an ever-changing array of interesting cloud features.

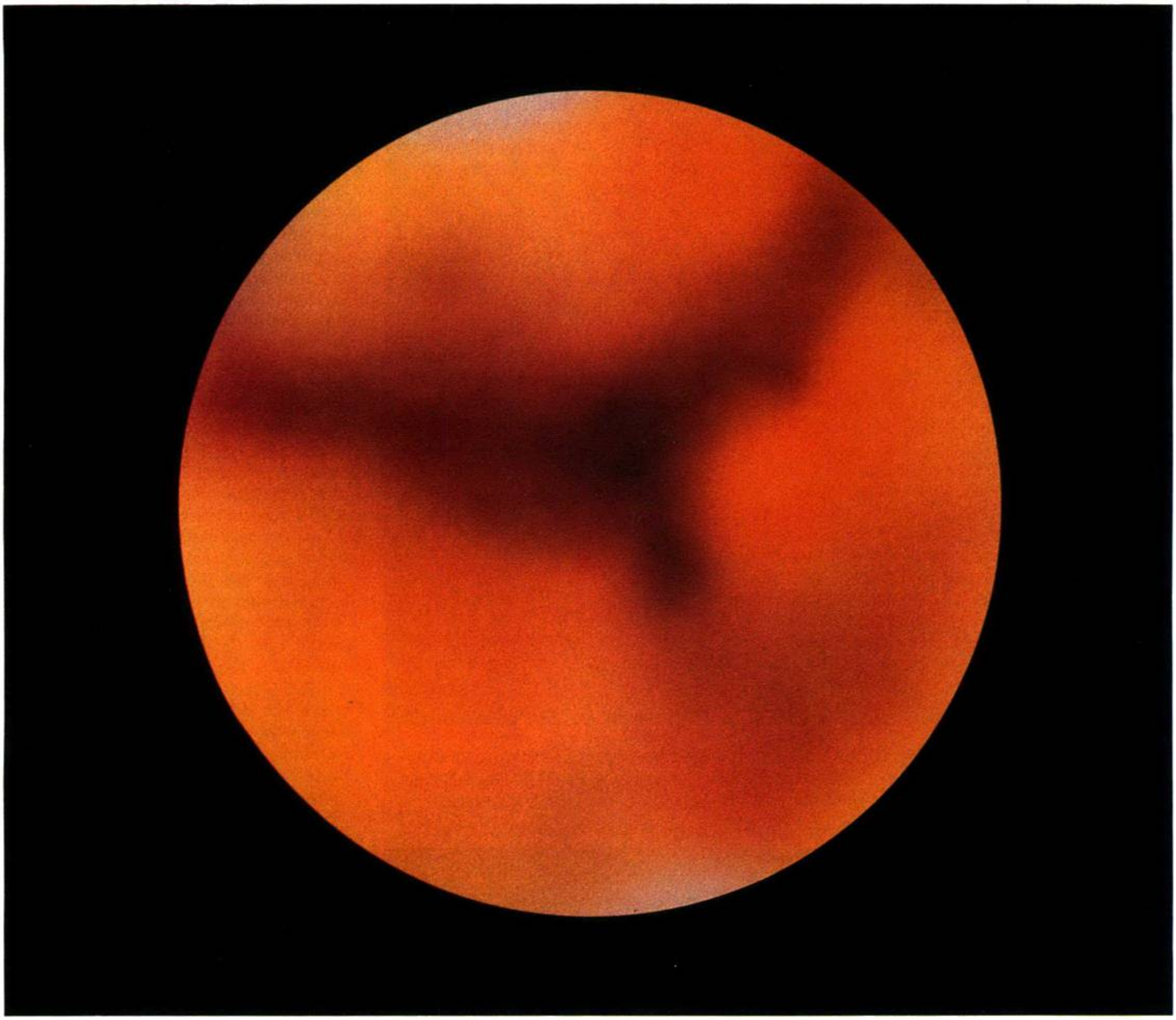
On November 27 the Red Planet reached opposition and put on its best show in two years. By then Mars had moved over to a spot between the Hyades and Pleiades star clusters in Taurus and shone brilliantly at magnitude –2.0. Moreover, the planet was a telescopic showpiece. Its diameter at this opposition was 18.1", large enough to provide observers with a detailed view of its many dusky markings and visible but somewhat elusive south polar cap. Although Mars wasn't as large as it was in 1988, this time it was much higher in the evening sky for Northern Hemisphere viewers. Mars observers had a field day.

Meanwhile, mighty Jupiter shone at magnitude –2.2 and, creamy white, it moved to a spot a few degrees east of the Beehive Cluster in Cancer. Rapt observers closely monitored the giant planet's disk, which measured 39.2" across. After experiencing last year's disappearance of the planet's normally prominent South Equatorial Belt, observers saw the SEB return to visibility, although it was not nearly as prominent as it had been for years before disappearing. Last November, observers recorded



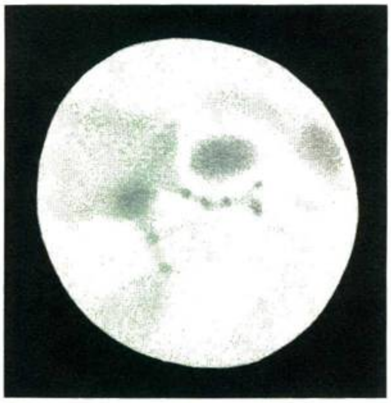
SYRTIS MAJOR dominates the Martian disk in this sketch made with a 10-inch f/10 SCT at 238x on October 22, 1990. Sketch by Clyde E. Kirkpatrick.

BRIGHT WHITE FROM HAZE, the Arabia basin was visible on November 18, 1990. The dark protrusion bordering Arabia is Meridiani Sinus. Photo by Gregory Terrance.

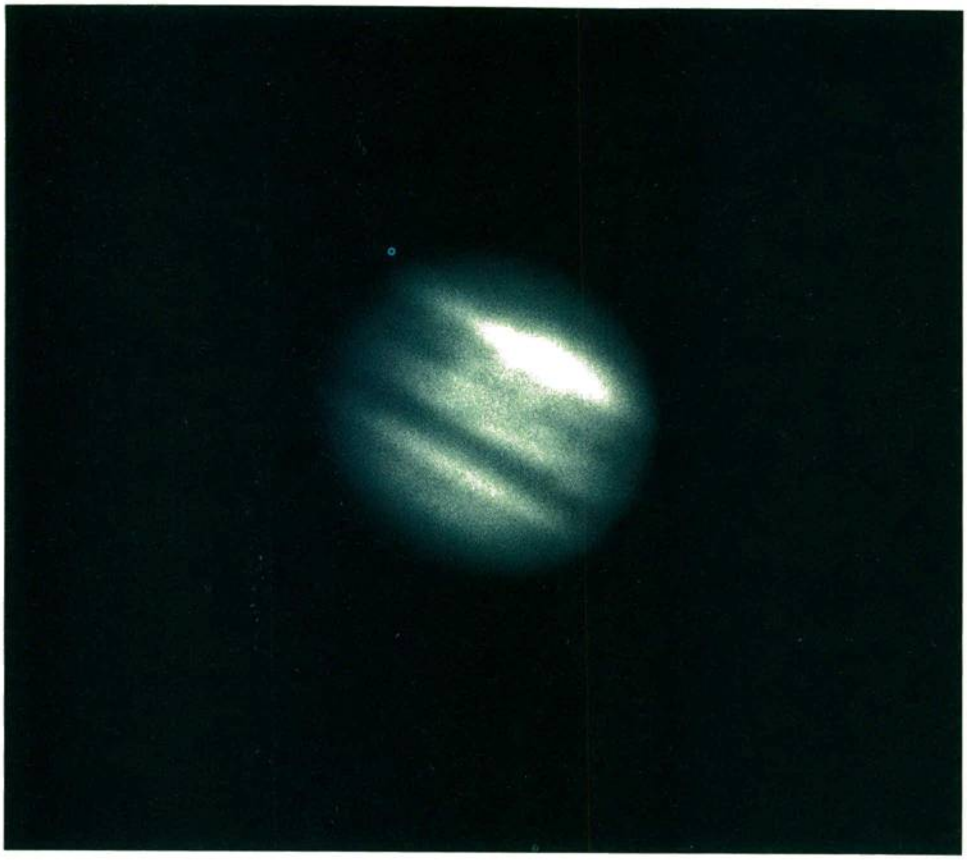


DUSKY MARKINGS ON AN ORANGE GLOBE characterized Mars' appearance throughout the 1990 apparition. Edwin Faughn made this painting from sketches with his 4-inch f/15 refractor at 160x and 240x on November 23, 1990.

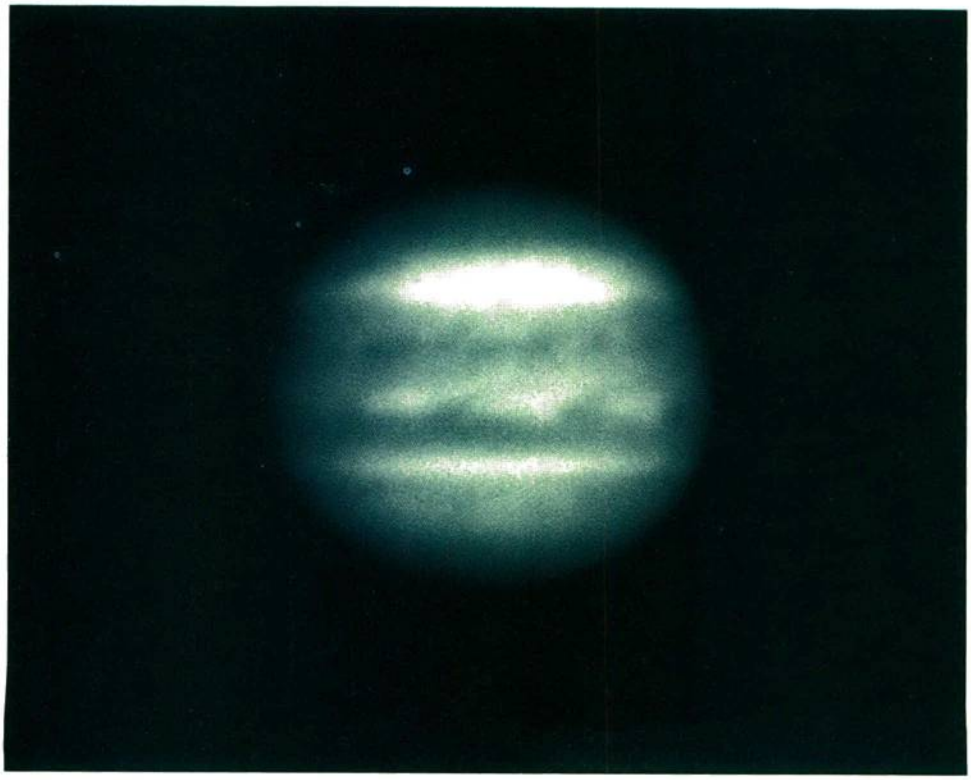
MARE ERYTHRAEUM, MARGARITIFER SINUS, AND AURORAE SINUS were all prominent dark blotches on November 21, 1990. Photo by Gregory Terrance.



INTRICATE DETAIL is visible in large telescope sketches of Mars. Russ Sampson made this sketch on October 4, 1990, using the 24-inch Clark refractor at Lowell Observatory.



NUMEROUS BELTS AND BRIGHT AND DARK CLUMPS were visible in Jupiter's atmosphere on October 27, 1990. The planet's South Equatorial Belt was not visible, but a bright band crossed Jupiter's southern hemisphere. Photo by Gregory Terrance.



JOVIAN FESTOONS were visible three weeks later, when the planet still appeared anomalously bright in its southern hemisphere. Photo by Gregory Terrance.

anomalously bright regions in the planet's southern hemisphere as well as a number of dazzling festoons and irregular bright and dark spots around the planet's set of belts and bands.

But the real excitement centered on Mars, and began in August when the planet grew larger than 10" across — large enough for a small scope to show surface details. By October 22, the planet swelled to 16" in diameter and was being followed by thousands of backyard observers. On that night, Clyde E. Kirkpatrick of Santa Barbara, California, carefully sketched the planet with a 10-inch f/10 SCT. Early in the evening, Kirkpatrick recorded a "prominent north polar hood and haze along the planet's morning limb." As Mars moved higher in the sky, Kirkpatrick noted that these features decreased slightly in brightness and the region of the south polar cap dimmed slightly.

Earlier in the month, on October 4, Russ Sampson of Edmonton, Alberta, Canada, realized a Mars observer's dream. While visiting Lowell Observatory in Flagstaff, Arizona, he had the opportunity to sketch the Red Planet with the observatory's 24-inch f/15 Clark refractor, the same instrument used by Percival Lowell. Sampson's drawing shows a dark, dominating Solis Lacus, small, dark knotty markings throughout Aurorae Sinus, and a possible dust storm in Sinai. "As luck would have it," says Sampson, "seeing conditions were exceptional. Lowell astronomer Brian Skiff said it was the best view of Mars he had ever had with the 24-inch scope!"

Gregory Terrance of Lima, New York, systematically photographed Mars at a large image scale and in high resolution from the outset of the opposition. He used a 16-inch f/5 reflector and employed eyepiece projection to achieve an effective focal ratio of f/135.

Terrance shot the planet every two weeks on Tech Pan film, using 1-second exposures, and achieved high-contrast details by developing the negatives in Rodinal at 1:25 for 14 minutes. Furthermore, he printed the negatives on high-contrast paper, producing in the final stage snappy photos of Martian surface detail.

Whether their aim was skillful photography or simply small scope peeks, amateurs once again were entranced by Mars and similarly bright Jupiter last autumn. It was another happy chapter in the lives of two bright planets. □

Pluto Meets the Serpent

ASTRONOMY's annual guide to observing Pluto will help you to find this elusive planet among the stars of Serpens.

by Richard Talcott

Nearly every backyard observer has a favorite solar system object. For some it is the eerie beauty of Saturn's rings. For others it's the intricate surface markings on Mars or the constantly changing positions of Jupiter's satellites. Although few observers would include Pluto on this list, that mysterious and intriguing world has a special charm all its own.

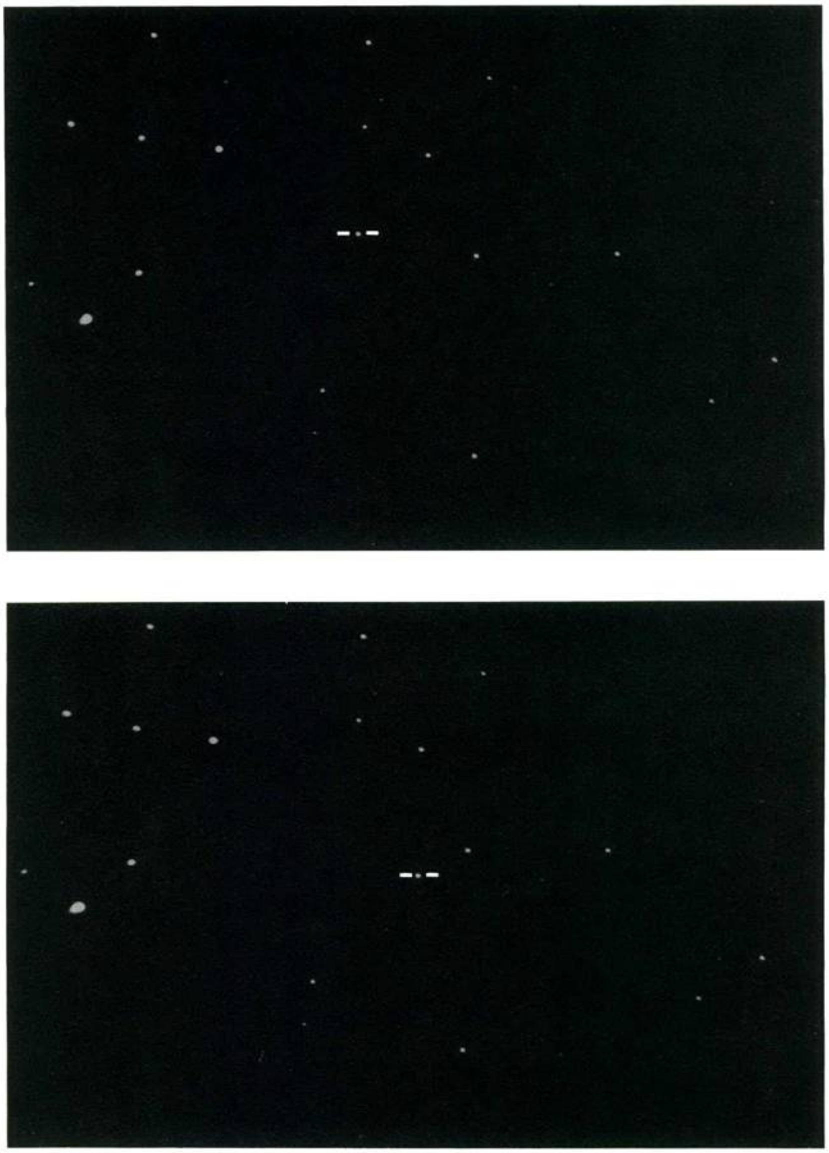
Pluto's charm stems from its unique characteristics. Pluto is smaller and fainter, and orbits farther from the Sun than any other planet. And because it's so faint — Neptune is more than 100 times brighter than Pluto — it is also the most challenging planet to spot.

Yet Pluto is not as difficult to locate as its reputation might lead you to believe. Anyone with a good 8-inch telescope can find the planet, *if* they know where and when to look.

This spring and summer offer an excellent opportunity to hunt down Pluto. Last year the planet was closer to Earth and thus brighter than at any other time in its 248-year orbit. This year the circumstances are almost as favorable because Pluto's orbital motion away from the Sun is so slow. When it reaches opposition on May 9/10 — when it appears opposite the Sun in the sky and is visible all night long — Pluto shines at magnitude 13.7, less than 0.1 magnitude fainter than it was at its best last year.

Beginning the Search

Although Pluto is comparatively bright this year, it is still a challenging object. To have a good chance of spotting it, you need a telescope at least 8 inches in aperture. A 10-inch or larger telescope will gather more of the faint planet's light and make the job of identifying Pluto easier. If you don't own a large telescope, consider observing with a friend who does. This will not only give you an opportunity to see Pluto that you might not get otherwise, but also allows you to share the experience.



IS THAT PLUTO? The only way to be sure you've found the elusive planet is to watch its position change from one day to another. Paul Roques captured Pluto's motion over a two-day period in June 1983.

The next requirement is a dark observing site. Your chances of finding Pluto from an urban or suburban setting are poor at best — the farther away you are from city lights, the better. You'll also want a site that offers reasonably steady seeing. Stay clear of parking lots, concrete buildings, and the like, and look instead for a park or other area that offers a large expanse of grass.

Finally, observe on a night when the Moon is out of the sky. The glare from anything more than a crescent Moon is more than enough to overwhelm the feeble light coming from Pluto. The best time to observe in April is during the period from April 11 to April 20. In May, New Moon falls on the 14th and you'll have a dark sky for a week before and after that date. The observing window in June runs from around June 5 to the 17th. And in July, you can observe from a week before the July 11 New Moon to three or four days after.

Zeroing in on Pluto

Once you have a telescope and site selected, all you need to do is wait for a clear, Moon-free night. When it comes, get out to your observing site early. The first thing to do when you arrive is set up your telescope so it can begin cooling to the ambient air temperature. The scope will probably take an hour or so to reach thermal equilibrium, during which time your eyes will have the chance to become fully dark-adapted.

You're now ready to track down Pluto. With the charts on these two pages, you'll be able to home in on Pluto's position on any given day by star hopping from some bright naked-eye stars to stars that are best seen in binoculars, and from there go to a telescopic field that contains Pluto. If you center that field in a medium-power eyepiece, you should be able to spot the 14th-magnitude interloper. To prove that the pinpoint of light you see is actually Pluto, you'll need to observe the same area of sky a night or two later to see whether the object has shifted position slightly as a result of its orbital motion.

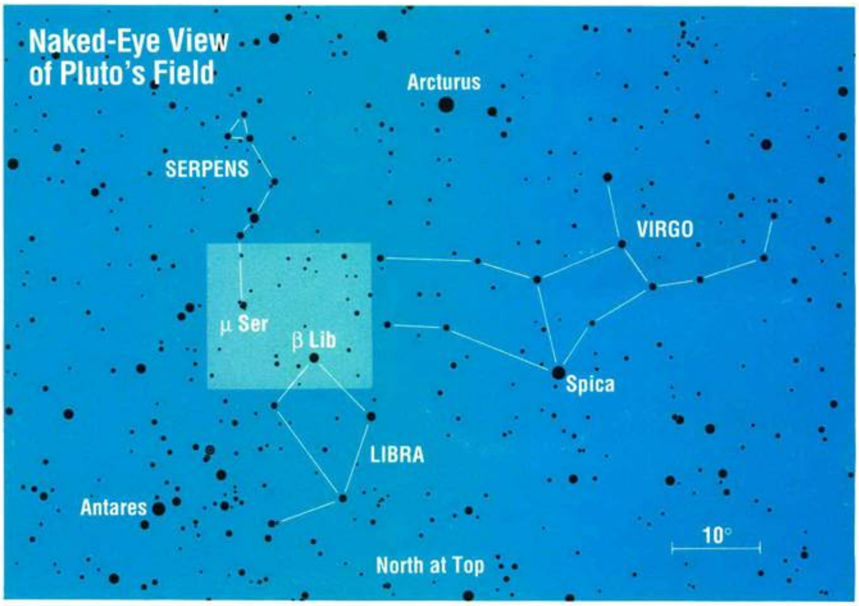
Even if you're new to observational astronomy, you can find Pluto. Here's how: Begin your quest with the bright star Arcturus. This orange-hued star shines at magnitude zero and is the brightest star in the spring sky. The easiest way to find Arcturus is by extending the curve of the Big Dipper's handle outward about 30°. If you then continue along that same arc for another 30°, you'll come to the second stop on our itinerary — the 1st-magnitude star Spica in Virgo.

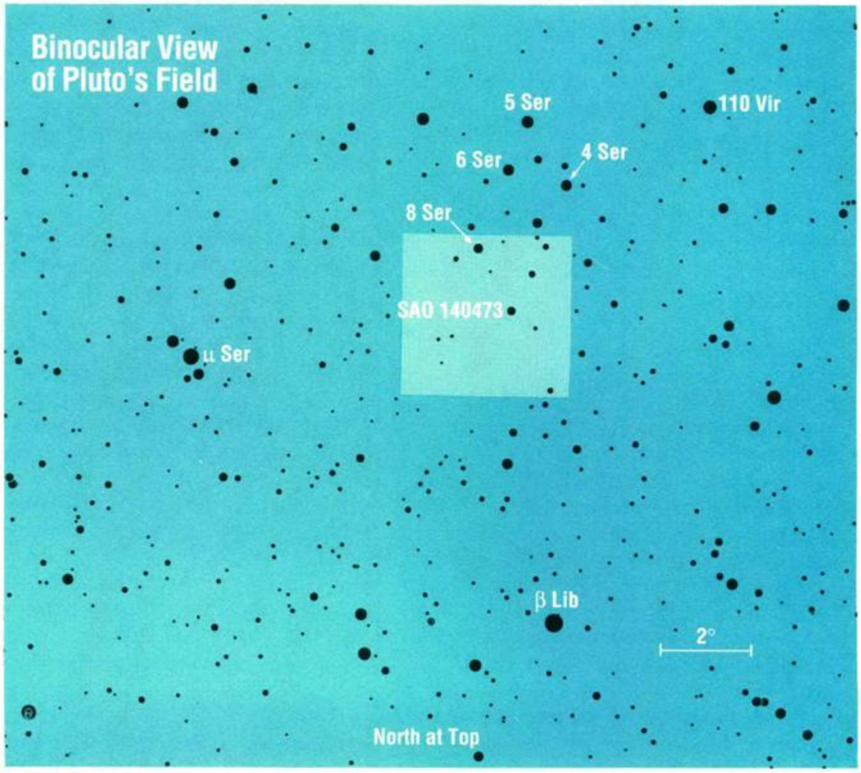
From Spica you want to head about 25° due east to the brightest star in Libra, 3rd-magnitude Beta (β) Librae. You're now set to make the leap from easy naked-eye stars to the fainter stars in the southwestern corner of Serpens Caput, or the Serpent's Head, which is where you'll find Pluto.

From Beta Librae head north roughly 10° — about two finder scope fields — to the small grouping of 6th- and 7th-magnitude stars that includes 4 Serpentis, 6 Serpentis, and 8 Serpentis. The 6.1-magnitude star 8 Serpentis is one of two key guide stars for finding Pluto this year. The other is a 6.4-magnitude star designated SAO 140473 that lies about 1.6° south-southwest of 8 Serpentis.

Pluto remains in the vicinity of these two stars throughout the year, although it is significantly closer to SAO 140473. In early May Pluto passes 1.5° due south of 8 Serpentis and in early June it passes just 5' north of SAO 140473.

Once you've located these two 6th-magnitude stars, you're ready to





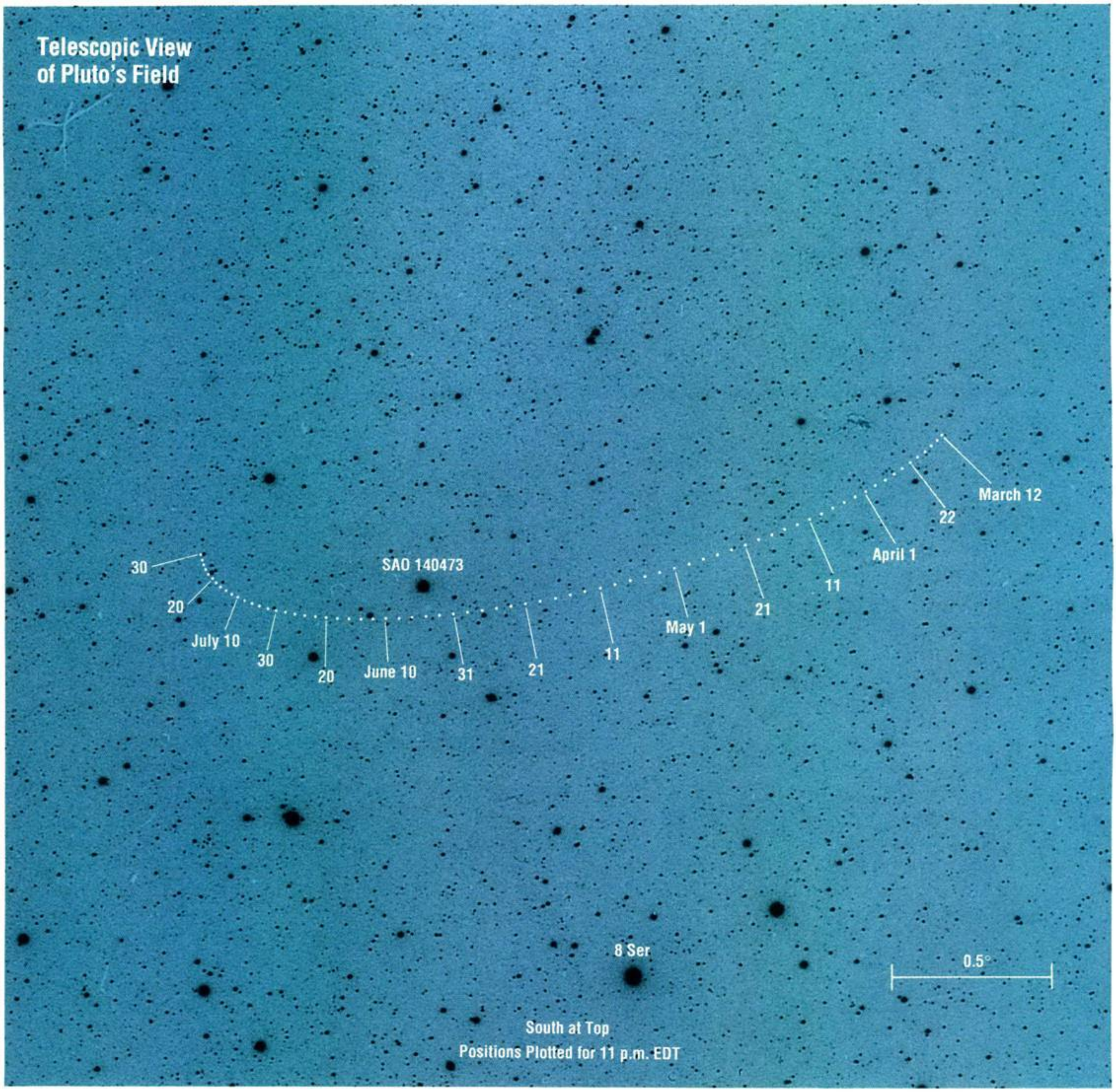
move to the telescopic finder chart. Find Pluto's position on the chart for the date you're observing and compare that area of sky to the view in a low-power eyepiece. (The positions shown are for 11 p.m. EDT, 10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT, though Pluto moves so slowly that the positions are quite accurate throughout a given night.) Then "star hop" from either 8 Serpentis or SAO 140473 to the right area by slowly moving your scope from one reasonably bright star to another.

Confirming the Find

Now center the expected position of Pluto in a low-power eyepiece and increase the magnification to about 10x per inch of aperture. By comparing the telescopic finder chart with your view in the eyepiece, you should be able to distinguish Pluto. But don't start congratulating yourself quite yet.

To confirm your identification of Pluto, you need to detect its motion against the background stars. First, make an accurate sketch of the Pluto field. Then observe the same field a night or two later and compare your original sketch with the current field of view. If the "star" you suspected to be Pluto has changed its position relative to the other stars, you were right.

Your success puts you in a select group of observers who have sighted this distant and challenging planet. And though you almost certainly won't view Pluto as often as you will Jupiter or Saturn, maybe you'll return to this intriguing world again next year, another backyard observer captured by the mystique of Pluto. □



Telescopic View of Pluto's Field

South at Top
Positions Plotted for 11 p.m. EDT

ASTRONOMY Tests the
Celestron PEC Drive

Celestron's Periodic Error Correction circuit makes long-exposure photography easier by automatically reducing tracking error. In our test, we found it reduced drive errors by a factor of ten.

by Alan Dyer

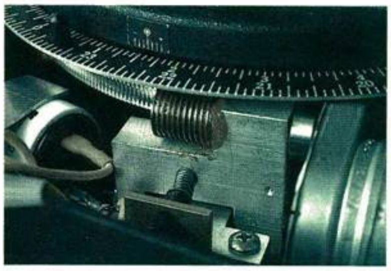
When I first heard that Celestron and Meade were working on electronic circuits that would automatically compensate for mechanical drive errors, I thought, "Sure, another gimmick. If companies would make the gears and mechanical drive system right in the first place they wouldn't need add-on circuits to correct tracking errors."

In part, this is true. A well-machined drive system is paramount for ensuring easy guiding and pinpoint star images in long-exposure astrophotos. Indeed, the drive in the Ultima 8 we used for this test has proven to be of very good quality. Now, to this well-made mechanical system, Celestron has added an electronic high-tech icing. Designed strictly for astrophotographers, the new Periodic Error Correction circuit helps reduce tracking error to levels difficult to achieve for a reasonable price by purely mechanical means. Celestron claims the tracking error of a drive is improved by a factor of three when using the PEC. We found this claim conservative. By using the PEC I found I could easily reduce tracking error by a factor of 10 to an impressive 3 arcseconds.

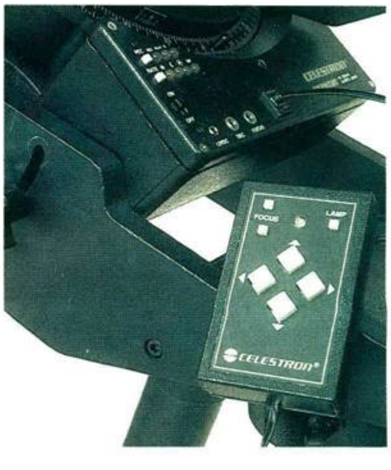
Trails of Woe

During long-exposure astrophotography, manual guiding corrections are essential to reduce gear-induced tracking errors on any telescope. But with bad drives, the errors can be so large and can come on so quickly that you can't compensate for them. The solution, if you have such a drive, isn't an electronic circuit. The solution is either fixing the drive or replacing it. As it turned out, that is exactly what we had to do to our test telescope's original drive. The Ultima 8 we purchased off-the-shelf in 1989 for a product review ("ASTRONOMY Tests the Ultima 8," May 1989) exhibited a large 100 arcsecond error. The error repeated every four minutes, the period of rotation of the worm gear. (See top photo, opposite.)

After we published the original review, Celestron assured us that indeed this amount of error was not typical and that the original drive was faulty. We received a replacement drive base and found that its periodic error was about 30 arcseconds (illustrated in the second photo from the top, opposite). This figure was far better and represents the minimum level of performance we



THE DRIVING MECHANISM of the Ultima is a worm-and-wheel gearing system. The new PEC circuit is designed to reduce the periodic speed errors that are inherent in any such drive system.



THE ULTIMA CONTROL PANEL features buttons for changing the drive rate and for activating the PEC circuit. The hand paddle provides a 2x fine-guiding speed or, if you hit two buttons at once, provides a faster 4x slewing speed.

would expect from a telescope designed for astrophotography. It is what you should expect from *any* Ultima telescope.

The error that remained showed up as a gentle undulation, with the guidestar gradually wandering in right ascension, first one direction then back the other, over a period of four minutes. It was this new drive that we then retrofitted with the PEC circuits for the review.

What the PEC Isn't

In the excitement over PEC devices, some misconceptions have arisen about how they work. In Celestron telescopes, the PEC is not a device you turn on and, like magic, drive errors disappear. As Celestron clearly points out in ads, the PEC feature is a circuit that memorizes your manual corrections, then plays them back. How good a compensation you get from the PEC circuit depends entirely on how good your manual guiding was during the "teaching" process.

The PEC feature works because on Celestron scopes most mechanical drive errors repeat with a period of four minutes. To train the PEC you switch it on "Record" for four minutes and guide normally. After four minutes, the PEC will automatically start playing back your corrections. You can continue to guide manually, adding a layer of still finer corrections. Four minutes later, the PEC electronics repeat the effect of each hit you make to the fast or slow buttons.

The biggest drawback to the PEC feature is that you have to retrain it every time you turn on the telescope drive. However, this is not a hardship. Ten minutes spent teaching the PEC will pay off through the rest of the night in greatly simplified guiding.

The Ultima offers a choice of four drive rates — sidereal, solar, lunar, and King. The King rate, named for the pioneering astrophotographer of the early 20th century, Edward King, turns the telescope at a slightly slower speed than the sidereal rate does. The difference between the two is one second of time per hour. The King rate helps compensate for the effects of atmospheric refraction.

Once you turn on the PEC functions, the Ultima drive locks on whatever drive rate you had selected at the time. You cannot switch from King to lunar, for example, without turning off the PEC, which erases the programming you've done to the PEC.

Testdriving the Drive

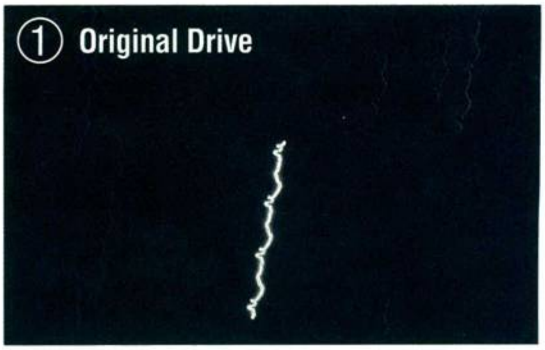
To evaluate the PEC, I test-guided using Celestron's projection reticle accessory. Its bull's-eye pattern of reticles made it easy to gauge the wanderings of the guidestar. With the PEC turned off, I confirmed the smooth 30-arcsecond back-and-forth drift. Putting the PEC into Record, I guided as much of this drift out as possible. After recording for four minutes, I played back my efforts and watched as the guidestar now moved through only 10 arcseconds.

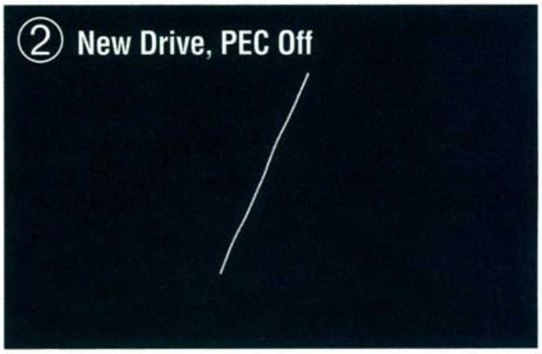
I then recorded for another four minutes and layered on another correction cycle. This brought the error down to 3 arcseconds. Another pass might have improved it further but at this point I was seeing a lot of random motion from atmospheric turbulence and residual non-periodic errors, something the PEC cannot correct.

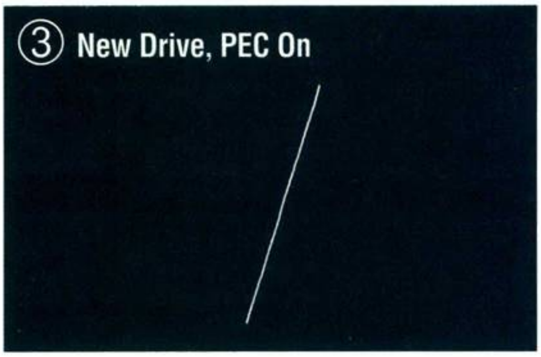
Having programmed the PEC, I deliberately shifted the polar axis of the scope to the west of the pole. Now, with a camera attached, I could record the effects of the PEC by letting a star drift in declination across the frame during the exposure. Any tracking error would show as a wiggle in the star trail. The results at right show a superb straight line trail with the PEC on and only a very slight wiggle (the 30 arcsecond error) with the PEC off.

For a final test, I recorded a pattern of deliberate mistracking to see how faithfully the PEC would reproduce my commands. I sent the guidestar east for 15 seconds, let the drive run at normal speed for 15 seconds, then hit the west button for 30 seconds. This was followed by another 15-second break, then 30 seconds of east motion, a 15-second break, then 15 seconds of west motion. This zig-zag sequence brought the star back to the center, where I let the drive run at normal speed for another 1 minute 30 seconds. I then capped the scope for 15 seconds to put a gap in the star trail. This pattern totalled 4 minutes. I then uncovered the scope and let the PEC play it all back for 4 minutes. The result is the bottom photo. The bottom half of the trail is the recorded pattern; the top half is the played-back version. The PEC played back my excursions quite faithfully, with only a slight decrease in amplitude and a slight rounding of the square-wave pattern. (The optional "Smooth" mode rounds off the played back pattern even more.)

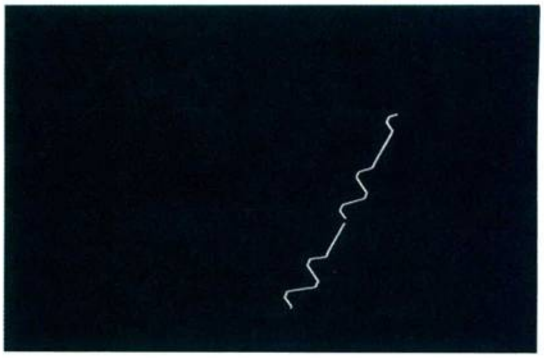
Overall, the PEC is impressive. It worked better than advertised. Coupled with a drive that is already free of large and sudden tracking errors, a periodic error correction circuit is a feature astrophotographers will soon come to consider essential. □







HAPPY (AND UNHAPPY) TRAILS: Photo #1 demonstrates the gross tracking errors of our original Ultima drive. Photo #2 shows the greatly improved replacement drive (with PEC off). Photo #3 shows the result of using the PEC — a textbook straight line. The two lower photos are both 8-minute exposures. All photos are reproduced full frame.



WITH WINDING TRAILS we found that the PEC drive faithfully played back guiding commands. See text for details.

The Galaxies of Sextans

Discover a beautiful and neglected collection of spirals and ellipticals tucked away in springtime's sky-bound sextant.

by David Higgins

Lodged between the constellations of Leo the Lion and Hydra the Water Serpent resides one of the faintest constellations in the spring sky. The brightest star in Sextans the Sextant glows dimly to the naked eye, barely breaking the 4th-magnitude mark. Sextans holds a powerful secret, however. Although it sits in an apparently blank region of sky, it is absolutely loaded with galaxies for observers with small telescopes.

The largest and brightest galaxy in Sextans is **NGC 3115**. Located in the southern half of the constellation, it is not far from the Sextans-Hydra border. To find NGC 3115, start at the 4th-magnitude star Gamma Sextantis. From Gamma move about 6° eastward and you'll find the 5th-magnitude star Epsilon, or 22 Sextantis. NGC 3115 lies just north of a line drawn between the two stars. If you don't find the galaxy on your first attempt, sweep around a bit — NGC 3115 is bright enough to see easily in a wide-field eyepiece. This galaxy is a magnitude 9.2 edge-on spiral with a very high surface brightness. Consequently, you should feel free to use high magnifications as you examine NGC 3115. In telescopes 2 inches to 4 inches in aperture, the galaxy appears as a spindle of light 3' long, oriented northwest-southeast and with little or no brightening in its center.

In a 6-inch or 8-inch telescope, NGC 3115's spindle lengthens to about 4'. The galaxy's nucleus is much easier to differentiate from the haze that surrounds it. NGC 3115 gives the appearance of a smooth glow surrounding a bright core. Two relatively bright stars are visible in the same low-power field as NGC 3115, one on the northwest edge and the other on the southeastern tip. In really large backyard scopes, the nucleus becomes very bright while the core becomes almost stellar and takes on a triangular shape. With the help of large telescopes, the length of NGC 3115 grows to almost 5'. You won't detect any hint of dust lanes in this spiral — even though a large number of edge-on spirals have them, NGC 3115 doesn't.

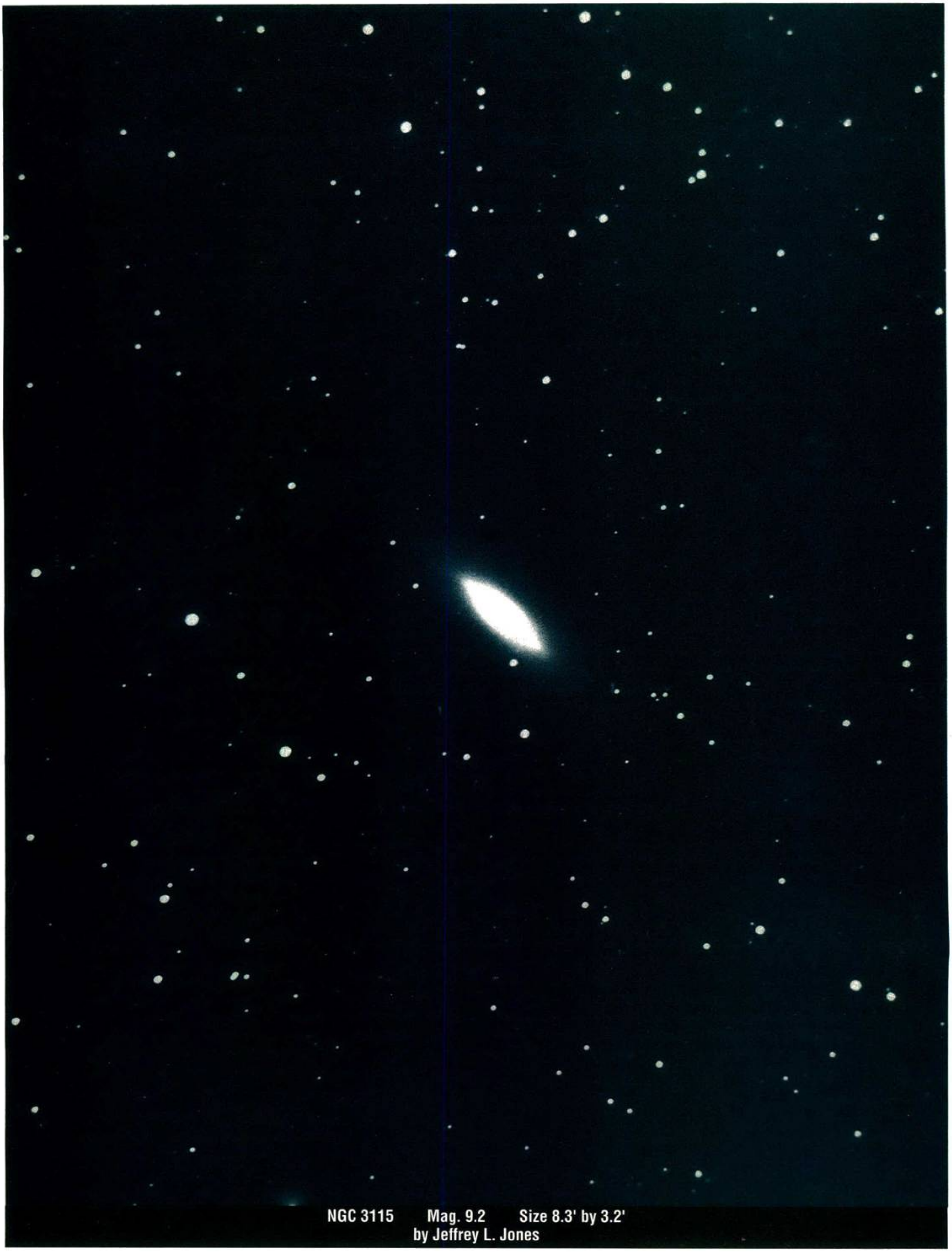
An interesting group of galaxies lies in the north-central part of Sextans. Lying 4.5° northeast of Alpha Sextantis you'll find NGC 3169, NGC 3166, NGC 3165, and NGC 3156. **NGC 3166** is a magnitude 10.6 face-on spiral that measures 5.2' by 2.7'. In small scopes it appears as an oval haze with some central brightening and is elongated east-west. In scopes larger than 10 inches aperture, the galaxy's central region appears brighter and the core is nearly stellar. This galaxy handles high magnification quite well, so don't hesitate to crank up the power after you've found it. No dust lanes or structural details are visible.

NGC 3169 lies about 8' northeast of NGC 3166 and glows at magnitude 10.5. Measuring 4.8' by 3.2', NGC 3169 is easily visible in small telescopes. A 4-incher shows NGC 3169 as an oval haze elongated northeast-southwest. There is very little central brightening. An 8-inch scope reveals a bright nucleus and star-like center. A faint field star lies just off the eastern edge of the galaxy. Southwest of NGC 3166, you'll find another galaxy well suited for small scopes. **NGC 3165** lies 5' southwest of NGC 3166 and glows dimly at magnitude 14.5. Measuring 1.6' by 0.9' in extent, NGC 3165 is visible in small scopes only with good skies and high magnification.

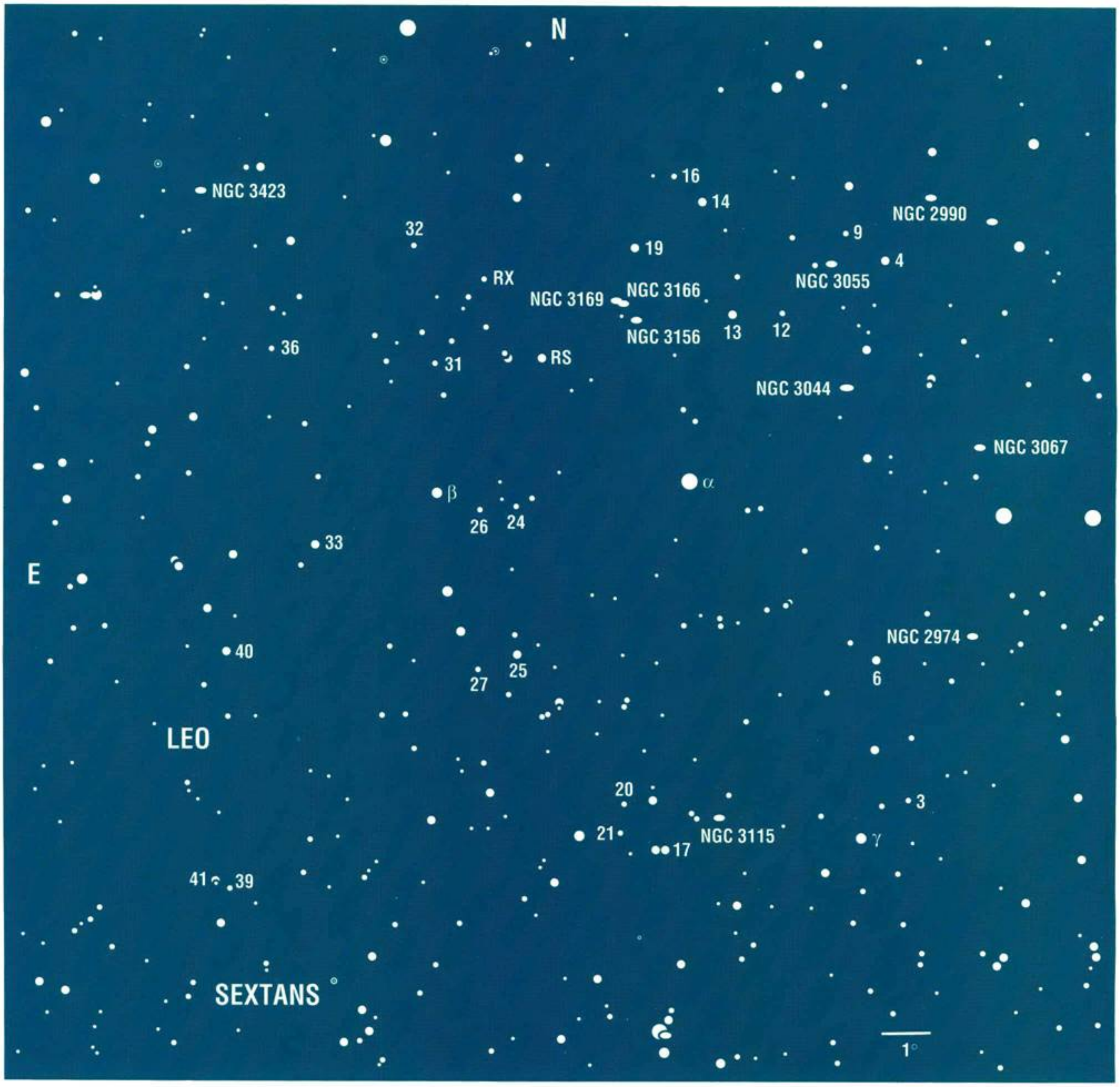
In large backyard scopes, NGC 3165 is an elongated haze orientated north-south. There is some hint of central brightening, and only very large scopes show a stellar core. One other galaxy in the area is situated 30' southwest of NGC 3166. **NGC 3156** is a small, 13th-magnitude spiral that measures 2.1' by 1.2'. It is not as faint as NGC 3165, but isn't as bright or as large as NGC 3166. In a 4-inch scope, NGC 3156 is a small, oval haze that does not show any central brightening. Elongated roughly northwest-southeast, NGC 3156 has a bright nucleus, but overall, the galaxy has a smooth, evenly lit appearance. NGC 3156 is situated at the western edge of a bright triangle of stars, which makes finding the galaxy easy.

In the northeastern corner of Sextans, practically on the Leo-Sextans border, lies a bright, face-on spiral with a magnitude of 11.2. Although it measures 3.9' by 3.5', **NGC 3423** is a little harder to find than most of the Sextans galaxies. Start at 5th-magnitude 59 Leonis and, using a wide-field eyepiece, move about 2° west. If you don't find NGC 3423 after carefully sweeping the area, recenter on your original position 2° west of 59 Leonis, insert a higher magnification eyepiece, and look more closely. In small scopes, NGC 3423 is an oval haze elongated north-south. The galaxy's nucleus is brighter than the surrounding haze and several field stars dot the area. In a 10-inch or larger scope, the nucleus is strikingly bright and bar-like in shape, and a hint of bright areas within the galaxy's hazy envelope are visible.

NGC 2990 lies in the northwestern corner of



NGC 3115 Mag. 9.2 Size 8.3' by 3.2'
by Jeffrey L. Jones


N
NGC 3423
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NGC 3156
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14
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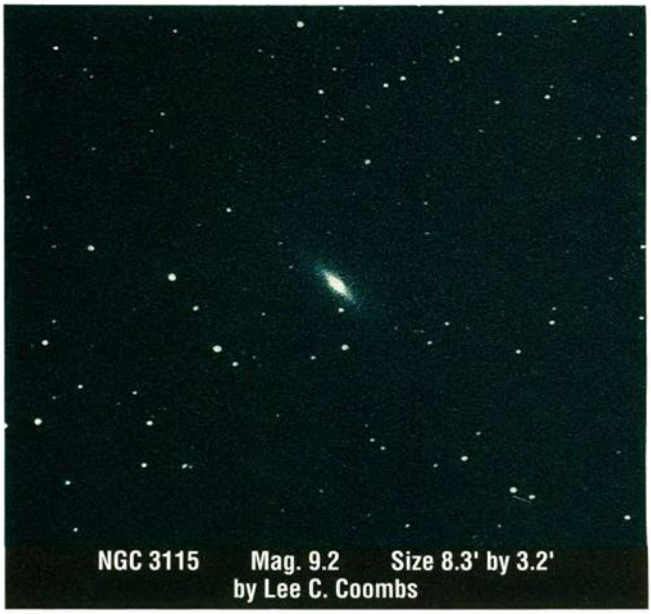
NGC 2990
NGC 3055
36
31
RS
NGC 3044
NGC 3067
α
β
26
24
33
E
40
25
27
NGC 2974
6
LEO
20
3
21
17
NGC 3115
γ
41
39
SEXTANS
1°

Galaxies in Sextans

Object	R.A.(2000.0)	Dec.	Mag.	Size
NGC 2967	9h42.1m	+0°20'	11.6	3.0' by 2.9'
NGC 2974	9h42.6m	-3°42'	10.8	3.4' by 2.1'
NGC 2990	9h46.3m	+5°43'	12.8	1.3' by 0.8'
NGC 3044	9h53.7m	+1°35'	12.0	4.8' by 0.9'
NGC 3055	9h55.3m	+4°16'	12.1	2.2' by 1.4'
NGC 3115	10h05.2m	-7°43'	9.2	8.3' by 3.2'
NGC 3156	10h12.7m	+3°08'	12.8_B	2.1' by 1.2'
NGC 3165	10h13.5m	+3°23'	14.5_P	1.6' by 0.9'
NGC 3166	10h13.8m	+3°26'	10.6	5.2' by 2.7'
NGC 3169	10h14.2m	+3°28'	10.5	4.8' by 3.2'
NGC 3423	10h51.2m	+5°50'	11.2	3.9' by 3.5'

Object: Designation in NGC catalog. **R.A.** and **Dec.:** Coordinates in equinox 2000.0. **Mag.:** V magnitude of galaxy; subscript B denotes blue magnitude and subscript P denotes photographic magnitude. **Size:** Diameter in arcminutes.



NGC 3115 **Mag. 9.2** **Size 8.3' by 3.2'**
by Lee C. Coombs

NGC 3166 Galaxy Group
by Preston S. Justis

Sextans. This small, magnitude 12.8 face-on spiral is much more difficult to see than the previous galaxies. Measuring 1.3' by 0.8', this galaxy's low surface brightness makes it a tough target for telescopes less than 8 inches in aperture. The easiest way to find NGC 2990 is to start by locating the stars 25 Sextantis and 2 Sextantis. NGC 2990 lies just east of these stars and forms a lopsided triangle with them. Once you locate NGC 2990, expect to see a faint, oval haze with very little central brightening. A faint field star lies northeast of the galaxy. In large scopes, the nucleus appears brighter than the surrounding haze.

Southeast of NGC 2990 lies **NGC 3055**. Brighter and a little larger than NGC 2990, NGC 3055 is another face-on spiral that glows at magnitude 12.1. Measuring 2.2' by 1.4', NGC 3055 is easier to find than NGC 2990. Draw an imaginary line from Alpha Sextantis to Omicron Leonis. NGC 3055 lies approximately midway between these stars. In small scopes this galaxy shows up as a small, concentrated haze. No hint of central brightening is visible. A faint field star lies on the southwestern edge of the galaxy. In large backyard scopes, NGC 3055 presents a different appearance. The galaxy appears larger and shows a relatively bright nucleus.

NGC 3044 lies south of NGC 3055. This edge-on spiral is a much easier target than NGC 3055. It appears at first glance to be a smaller copy of NGC 3115. Not as bright or as large as NGC 3115, however, NGC 3044 glows meekly at magnitude 12 and spans 4.8' by 0.9'. Finding NGC 3044 is easy: Start at Alpha Sextantis and draw an imaginary line to the 5th-magnitude star 2 Sextantis. The galaxy lies midway between these two stars. Because NGC 3044 has a relatively low surface brightness, small scope users should employ moderately high magnifications to increase the contrast when observing this spiral.

NGC 2967 is a face-on spiral that glows at magnitude 11.6 and measures 3.0' by 2.9'. To find NGC 2967, start with Iota Hydrae and move about 1.5° northeast. In small scopes this object appears as a faint glow with some central brightening. In larger scopes the nucleus is brighter and easier to distinguish from the haze surrounding it. Overall, NGC 2967 is fairly concentrated toward its center but does not show a star-like nucleus. Now return to Iota Hydrae and use it as a starting point to find **NGC 2974**. This galaxy lies 3° southeast of Iota Hydrae. About the same size as NGC 2967, NGC 2974 is brighter and has a higher surface brightness. With a magnitude of 10.8 and dimensions of 3.4' by 2.1' it is visible in the low-power eyepiece of small scopes.

Sextans is not a bright constellation, nor does it have large, bright galaxies that make it a favorite of most observers. But the galaxies that do reside in Sextans will surprise you. Spend the time and make the effort to find some of the hidden galaxies of Sextans — you'll get valuable practice in star hopping techniques, the opportunity to observe little-known objects, and a keener eye for critically viewing these distant islands of stars. ☐

David Higgins is central coordinator of the National Deep Sky Observers Society and a contributing editor of Deep Sky *magazine.*

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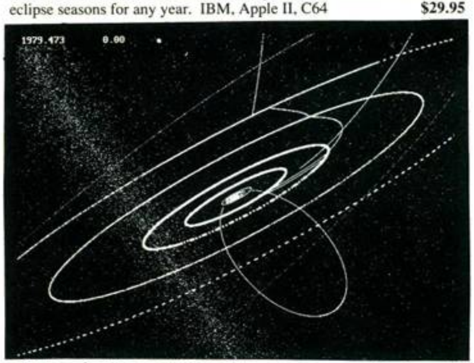

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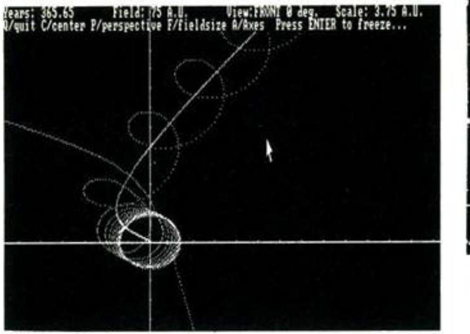

```
Years: 365.65      Field: 75 A.U.      View:FRONT 0 deg.   Scale: 3.75 A.U.
Q/quit C/center P/perspective F/fieldsize A/Axes  Press ENTER to freeze...
```

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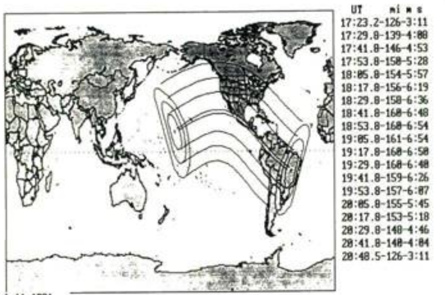

```
UT      mi m s
17:23.2-126-3:11
17:29.0-139-4:00
17:41.0-146-4:53
17:53.0-150-5:28
18:05.0-154-5:57
18:17.0-156-6:19
18:29.0-158-6:36
18:41.0-160-6:48
18:53.0-160-6:54
19:05.0-161-6:54
19:17.0-160-6:58
19:29.0-160-6:40
19:41.0-159-6:26
19:53.0-157-6:07
20:05.0-155-5:45
20:17.0-153-5:18
20:29.0-140-4:46
20:41.0-140-4:04
20:48.5-126-3:11

Jul 11 1991
Saros 136 Rel.No. 0 Enter B=Bound Plot,P=Cent. Path Data,Q=Quit
```

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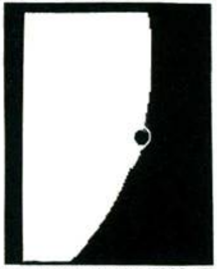
Orion the Hunter



Venus Transit 7/11/5900AD

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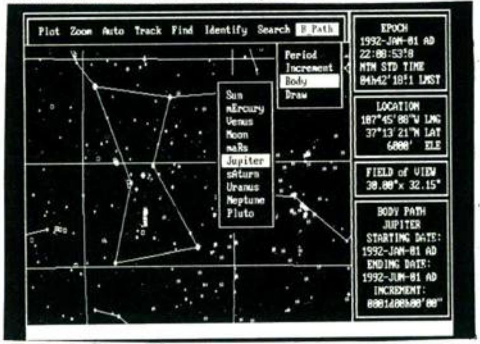

```
EPOCH
1992-JAN-01 AD
22:00:53.8
MTN STD TIME
04h42'18.1 LMST

LOCATION
107°45'00"W LNG
37°13'21"N LAT
6000' ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
JUPITER
STARTING DATE:
1992-JAN-01 AD
ENDING DATE:
1992-JUN-01 AD
INCREMENT:
0001d00h00'00"
```

☐ **LodeStar Plus™** All features of 2.1 version and these additions: High resolution 16 colors with EGA/VGA modes. Includes all 7840 NGC galaxies, clusters, nebulae, etc. Options to plot RA&Dec grids and constellation boundaries. Automatically search for and see solar and lunar eclipses, planetary conjunctions, occultations. Plot the paths of Sun, Moon & planets on sky view. Video mode lets you record screens to display later for reference or demonstrations. Calculates parallax, nutation and abberation and ephemeris time corrections for high accuracy. Supports any of 300 printers, dot, laser or jet. Sophisticated interface including pull-down menus and mouse support to easily access all 78 functions. IBM & compat. 512K, Hercules, CGA/EGA/VGA. Works with or w/o co-processor. 16 colors w/ EGA/VGA **$149.95** (Demo **$10.00**)

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Astronomical Society of the Pacific, HST Slide Orders Dept., 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100. $29.95. Orders outside the U.S. please remit in U.S. funds; California orders please add sales tax.

2 New Astronomy Videos

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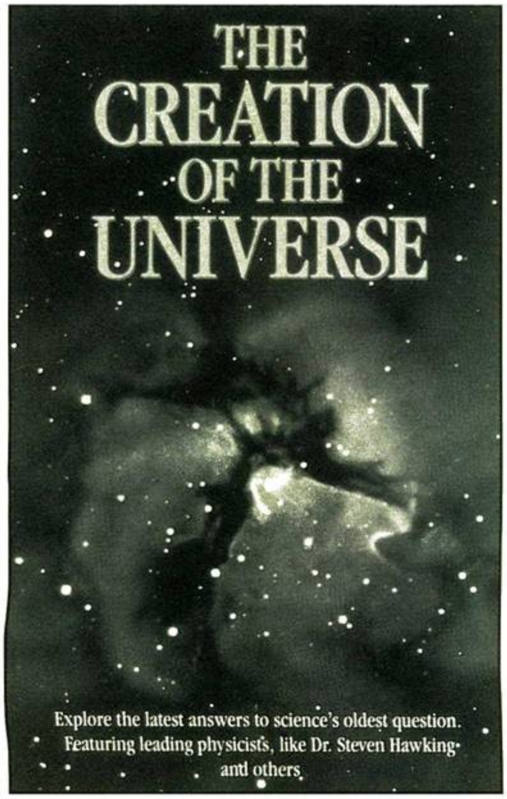
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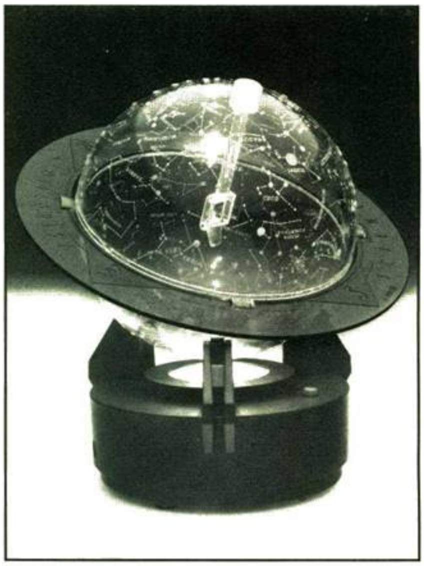

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Galaxies M81 (left) and M82 (right) in Ursa Major. 30 minute exposure by Martin Germano using 103aF, and an 8" f/5 telescope with a LUMICON 2" Newtonian EASY-GUIDER. Visually M82 shows much mottling and detail. Spiral detail in M81 is hard to see visually.

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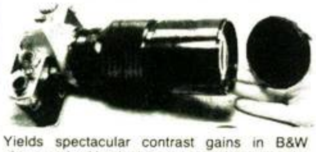

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67, 72, 77mm	**$69.00**	**$59.00**
82mm	**$79.00**	**N/A**

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

LUMICON®
2111 Research Dr #5A, Livermore, CA 94550
For phone orders please call (415) 447-9570
FAX (6 PM-9 AM PST) (415) 447-9589
LUYMICON Products catalogue FREE
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Prices subject to change w/o notice.
Hrs: M-F 9 am - 5 pm, Sat. 11 am - 3 pm

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. 1.3-1.8" mirrors have enhanced silver coatings (98-99%R). The extra 8-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**
4.25"	**$149.50**	4.00"	**$149.00**		

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

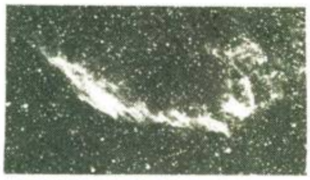
1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$159.00**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 90-97%.



"I CAN SEE THE VEIL NEBULA!"
Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter or the LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 85-95%.

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Set of Both premium **DEEP-SKY** and **UHC Filters** (Save 11%), Premium	**$159.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295**

MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$295**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**
Guider for Hasselblad **$350**, Mamiya 645	**$199**
Adapter for Pentax 6x7 med. format	**$89**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER	**$225.00**
Adapter for Hasselblad **$185**, Mamiya 645	**$159**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**
Adapter for Hasselblad **$195**, Mamiya	**$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector** . **$219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. **$99**
NEW Deluxe Digital Qtz. Drive Correc. **$298**

NEW
SRV3200

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SRV3200, fastest of all, color neg	24	**$13.95**
Konica SR-V3200, unhypered	24	**$8.50**
Konica SR400, fine grain color neg	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

LUMICON means INNOVATION

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IMPROVED LUMICON® SKY VECTOR II™ $589

Now 1500 of "Best" Deep-Sky Objects in Computer Memory

LOW PRICE—from $399

LUMICON SKY VECTOR FEATURES:

- Digital right ascension readout to 1 minute of right ascension (RA)
- Digital decl. readout to 10 arc-min
- 4000 pulse (0.09° accuracy) high resolution encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, date, sidereal time, etc.
- 9V Battery lasts many nights.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision high resolution digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

LUMICON SKY VECTOR™ for Meade 2080, Meade 2120 *(Specify)*	**$399**
For Celestron C-8, C-11 *(Specify)*	**$399**
For Coulter Odyssey 8", 10", 13", 17½"	**$399**
For any alt-azimuth (Dobsonian) scope	**$399**
For Celestron C-14 (rewire dec. motor)	**$498**
SKY VECTOR KIT (for skilled ATM's)	**$369**

Reference catalogues (1000's of objects)

Burnham's *Celestial Handbook*, I, II, III	**$36.85**
Revised New General Catalogue (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II	**$29.95**

Only the LUMICON SKY VECTOR II has size, true **visual** magnitude, and complete **visual** appearance description for **all** 1500 objects in memory.

OFF ON
DIM
1735+273
RA
DEC
MODE
STAR
UP
DOWN
Sky Vector II™
COMPUTER SETTING CIRCLES
LUMICON®

LUMICON SKY VECTOR II™ Computer with 1500 object memory, digital readout of coordinates, easy-to-use controls, object size, visual magnitude and visual appearance descriptions.

Please specify telescope type:

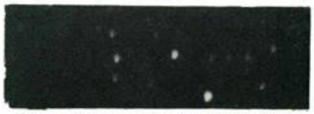
LUMICON SKY VECTOR II™ for Meade 2080, Meade 2120 (*Please specify)*	**$589**
For Celestron C-8, C-11 *(Specify)*	**$589**
For Celestron C-14 (rewire dec. motor)	**$665**
For Coulter Odyssey 8",10",13"17½"	**$589**
For any alt-azimuth (Dobsonian) scope	**$589**
SKY VECTOR II (upgrade, computer only)	**$395**

The **LUMICON SKY VECTOR II**™ has all the features of the regular SKY VECTOR, but has 1500 of the best deep-sky objects in memory, selected by noted observer Steve Gottlieb, along with their coordinates, size, true visual magnitude, and other descriptive data. The sophisticated computer programming also will guide you to the object selected by displaying the real-time angular separation. Just move the telescope until the angles displayed become "0" using the "GUIDE" mode.

LUMICON SKY VECTOR II FEATURES:

- Includes **size, true visual magnitude & complete visual appearance description** for all 1500 objects
- All 110 Messier objects
- Brightest 31 alignment stars
- User definable catalogue of 25 objects retained in memory
- 703 galaxies, groups & clusters
- 228 best open star clusters
- 170 best planetary nebulae
- 77 emission & reflection nebulae
- 10 best dark nebulae
- 107 best gobular star clusters
- 205 best colored & multiple stars
- Displays Uranometria 2000.0 chart no.
- ROM upgradable for planets, extended object lists, etc.
- TIMER function, elapsed time & stop watch
- 2 star alignment for alt-azimuth or equatorial telescope systems
- 1 star alignment if polar aligned
- Uses Epoch 2000.0 coordinates
- May align on any of the 1500 objects in memory

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces. Clear aperture = 1.8".

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

MEADE® TELESCOPES

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550
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LUMICON ACCESSORIES

NEW PREMIER SERIES TELESCOPES

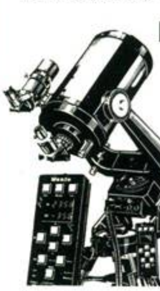
All Meade Premier Series telescopes **include Smart Drive (SD) permanent periodic error correction**, multi-coated enhanced optics (MCOG), Electronic Command Center (ECC), and **include** advanced LX6 all-electronic drive system. Select f/10 or f/6 optics, and select only the optional features you **need.** The 8" has a 6X30 finderscope and the 10" has an 8X50 finderscope. SD = Smart Drive.

2080 Model 40SD, 8" f/10	**$1650**
2080 Model 46SD, 8" f/6	**$1799**
2120 Model 40SD, 10" f/10	**$2099**
2120 Model 46SD, 10" f/6	**$2298**
Model 2600 16" f/10	**$9950**

Options Enhance Performance

Super Wedge for 10"	**Add $299**
ECC Electronic Command Center	**$275**
#39 Declination motor	**Add $109**
Digital setting circle	**Add $399**
2" Star diagonal	**Add $179**
LUMICON Cassegrain Easy-Guider *(Please specify camera)*	**Add $225**
LUMICON Giant Easy-Guider (for #40) *(Specify camera)*	**Add $395**
LUMICON Giant Easy-Guider (for #46) *(Specify camera)*	**Add $295**

PREMIER 2080 MODEL 50SD $1950



Meade Premier 2080 Model 50SD

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89;** 32mm **$109**

Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**

Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2045D 4" f/10 w/motor drive	**$695**
2080A Standard 8" f/10 w/tripod	**$999**
2080B Std. w/tripod, MCOG	**$1099**
2080 Model 50SD, 8" f/10	**$1950**
2120 Model 50SD, 10" f/10	**$2399**
2120 Model 50SDH, 10" f/10 w/Super Wedge, Smart Drive	**$2698**
2080 Model 56SD, 8" f/6.3	**$2099**
2120 Model 56SD, 10" f/6.3	**$2595**
2120 Model 56SDH, 10" f/6.3 w/Super Wedge, Smart Drive	**$2894**
Dew shield - essential! 8" **$119;** 10"	**$129**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$898**
SPECIAL PROMOTION	
Model DS-10A, 10" f/4.5 with motor, 2" focuser	**$775**
Model DS-16AB, 16" f/4.5 w/motor, 2" focuser, Sealmaster ball bearings	**$1875**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

2" DELUXE BARLOW

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x multiplier lens ... **$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $49.50

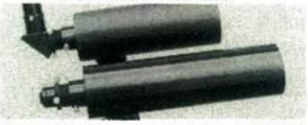
LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser 1½" high	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra. The

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$37**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher, C-6, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**

A SAMPLER OF NEW SOFTWARE

This is truly a golden age for armchair astronomers. With a home computer and some suitable astronomy software, you can explore the heavens in ways not possible with books, star charts, planetariums, even a telescope itself. One key advantage of many programs is that they allow you to explore time as well as space, showing you accelerated motions of the heavens or the skies thousands of years in the past or future. Anyone with a home computer and an interest in astronomy will want to own at least one major astronomy software product, if not several. The new programs that ASTRONOMY has received in the last few months reflect the variety of software available these days.

Astronomy Lab, (Personal MicroCosms, 8547 E. Arapahoe Road, Suite J-147, Greenwood Village, CO 80112, (303) 753-3268). $59.95 plus $2.95 postage and handling.

Astronomy Lab can produce animated movies that simulate the motions of the night sky and solar system objects, including close-up views of Jupiter's moons. It can also show animation of the seasonal changes in the pattern of day and night over the surface of the Earth. This software can generate graphic representations of the year's sky activity using plots of the positions, magnitudes, percent illumination, distances, and apparent diameters of planets. You can also explore the changing angle of the Sun and the motion of the sunrise point through a given year. A unique feature is the ability to print out calendar-style reports showing the rise and set times of the Sun and Moon, as well as times of key lunar phases. Astronomy Lab requires an IBM PC or compatible, AT or above recommended, with at least 512K of memory, and MS-DOS 3.0 or higher. It is available on either 5 1/4- or 3 1/2-inch diskettes and comes with a 153-page user's manual.

Night Sky 4.0, (Southwest Astronomy, 4242 Roma N.E., Albuquerque, NM 87108, (505) 255-9573). Standard version: $59.95; Expanded version: $79.95.

Designed for beginning astronomers, Night Sky can generate star charts and time-lapse displays of planet and comet motions set against those star charts. It can also produce tables of Sun, Moon, and planet positions, as well as graphics

AUCTION CATALOG & REFERENCE GUIDE

NOW READY — $12.00

Over 400 quality items with 50 photos will be in our May 18th auction catalog. This may be the best single reference source of telescopes, binoculars and other optical instruments in existence. The $12.00 price includes a prices-realized sheet.

We have a magnificent variety of collectibles! Even members of our staff are astonished at the rarity and museum-like quality of numerous entries. We urge your attendance and participation in this important event.

More consignment samplings: Signed 2″ obsidian flat by Russell Porter, 1896 Mars globe by Camille Flammarion, signed 1925 watercolor by Russell Porter entitled "2 A.M.", 10″ mirror circa 1910 by Rev. W.F.A. Ellison with 30 pgs. of correspondance between Albert Ingalls and Ellison, 4 original space paintings by Bergeron, 2 early speculum gratings by Fecker, original hand crafted 1/16″ scale model of the Palomar 200″ Hale Telescope by Cliff Raible (described in Nov. 1947 SKY & TELESCOPE), 5 papers by William Herschel dated 1791-1801, nearly complete set of original Popular Astronomy journals from 1892-1951, WWI 125mm 20× Nikko artillary binoculars, 19th Century Dolland Twin Telescopes with 11″ leather-covered brass tubes, rare 7×50H Zeiss Septar made for Swedish Navy, original 13′ long 1856 Fitz mahogany refractor tube from West Point.

We invite you to join us in what may possibly be the largest assemblage of astronomical and optical equipment ever gathered under one roof. The auction will commence at 11 AM on Sat., May 18th. Preview is Fri. 7-9 PM and Sat. 9-11 AM. Mail or absentee bids will be accepted and three lines are available for telephone bids. However, we highly recommend that you attend in person.

PLEASE NOTE: Due to the number of larger instruments now consigned to the auction, we have been forced to larger quarters. The auction will now be held at Mapes Auction Gallery in Vestal, New York, located a few miles east of Owego on Route 434. Exact directions and a list of nearby motels are included in the auction catalog. Broome Co. Airport in Binghamton is 20 minutes from the gallery.

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-Unique Portable Design
-Innovative Eq. Table for Precision Tracking
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of the positions of Jupiter's moons. Night Sky requires an IBM or compatible with a minimum of 360K of memory and MS-DOS 2.0 or higher. It comes with an 18-page user's manual. The standard version comes with a 9,800-star database; the expanded version has a 50,000-star database.

HIPPARCHUS, (sofTouch APpLications, 646 North Bend Road, Baltimore, MD 21290). $49.95 plus $2.35 shipping and handling.

HIPPARCHUS will produce star charts in either Mercator or polar projection at any scale, using the 9,096 stars in the Yale *Bright Star Catalog*. A unique feature is the ability to show the proper motions of stars over tens of thousands of years, illustrating the changing patterns of the constellations. Stars may also be shown indicated with their magnitudes or with a variety of catalog designations. HIPPARCHUS is for Macintosh computers with a minimum of 1 megabyte of memory. It comes with an extensive user's manual.

From Z-2-Astronomy, (Z2 Computer Solutions, 439 Molino Avenue, Sunnyvale, CA 94086-7552, (408) 735-7807). $59.95 plus $3.50 postage and handling.

The primary application of this software is for computing the positions of the Moon, planets, and 67 bright stars for historical studies. The program will compute the rising and setting times for selected planets and stars, conjunctions, and alignments between any two objects — as well as solar and lunar eclipses — all to positional accuracies of arcseconds. The program's range is from 4001 BC to 8000 AD. From Z-2-Astronomy requires an IBM or compatible with a hard disk and 512K of memory.

STSORBIT, (David H. Ransom, Jr., 7130 Avenida Altisima, Rancho Palos Verdes, CA 90274, (213) 377-1849). Free (public domain); contact the author.

One of several such programs in the pubic domain market, STSORBIT calculates the positions and visibilities of Earth-orbiting satellites from user-entered orbit data. The program will print an Earth map showing the ground track of the satellite. STSORBIT requires an IBM or compatible computer.

Program developers and software companies are invited to send their new product announcements and sample review copies to ASTRONOMY, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187 — Attention: Alan Dyer. ☐

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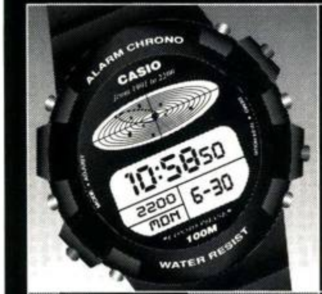

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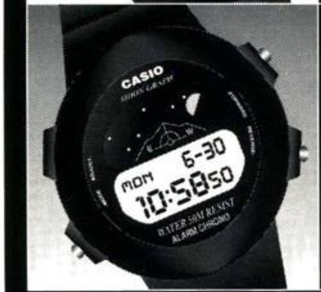

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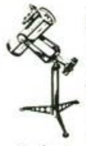

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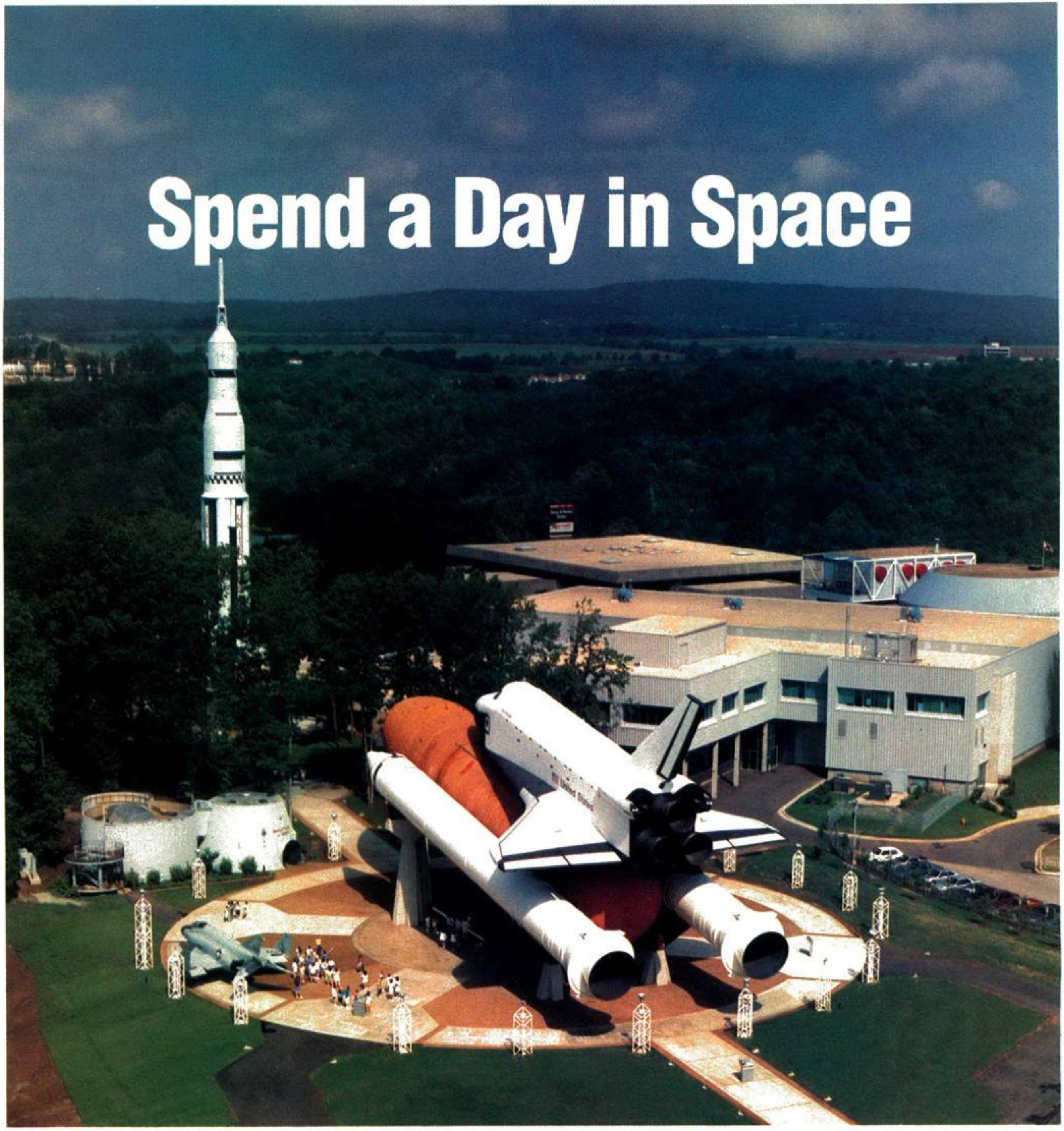

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Astronomy Books

AN EYE-APPEALING VIEW OF ASTRONOMY

Our Universe: an Armchair Guide, by Michael Rowan-Robinson, (W. H. Freeman and Company, 1990), ISBN 0-7167-2156-2, 180 pages, sewn binding, hardcover, $24.95.

British astronomer Michael Rowan-Robinson has chosen 20 familiar astronomical objects as springboard vehicles, using each as an example to introduce and describe a portion of the universe.

The author abandons the usual linear Earth-to-Sun, solar system-to-galaxy approach. Instead, the book opens with a chapter on Halley's Comet in which readers learn about comets, asteroids, meteors, and the electromagnetic spectrum. The next chapter, titled "Alpha Centauri," investigates parallax and stellar proper motion. "Sirius and its White Dwarf Companion" is next and touches upon white dwarfs and neutron stars. And so it goes as readers are introduced, one by one, to the major areas of astronomy.

The volume is visually attractive and rich with color, with more than 350 astrophotos and images. Most of the former are from Earth-based telescopes but space images from satellite observatories are also used to good advantage.

Each of the 21 chapters is preceded by a page on which there is a splash of abstract color, reminiscent of something a contemporary artist might render. The same page also carries a brief literary quotation alluding to the chapter's topic. This design feature is pretty, but I note that it gives a total of 21 pages to material of questionable value in an armchair guide to the universe. Quibbles aside, however, the color renderings throughout the book are sharp and clear, and if their content doesn't always seem appropriate, they are pleasing to look at on a cloudy evening.

A few errors are evident. On page 59 Rowan-Robinson misidentifies Bellatrix, the brilliant star marking the left shoulder of the cosmic giant, as one of the three belt stars. Also, on page 65 the captions for photos of the Trifid Nebula and NGC 2264 are transposed.

While this is not an outstanding book, it is a good book for its intended audience: the curious reader interested in astronomy who is willing to spend a few hours with an eye-appealing volume written by a professional astronomer. — *Gail O. Clark*

Observing

The AAVSO Variable Star Atlas, 2nd edition, prepared by Charles E. Scoville, (American Association of Variable Star Observers, 1990), ISBN 1-878174-00-2, 205 pages in loose-leaf binder, $49.95.

The atlas contains 178 charts, depicting the entire sky and plotting stars to 9th magnitude. Each chart covers a little over 1 hour of right ascension and about 18° of declination. Ordinary stars are plotted as dots, while variables are shown as open circles; the latter are labeled with their names, the former with Greek letters. Selected non-stellar objects (galaxies, clusters, nebulae) are shown by special symbols that generally resemble those used in atlases such as *Sky Atlas 2000.0* and *Uranometria.* (The objects are not identified, however.) After the atlas is an index which lists the variables in each constellation, their type and magnitude ranges, and the charts on which they appear. (Order from the AAVSO, 25 Birch St., Cambridge, MA 02138.)

The Solar System

Uranus, by Ellis D. Miner, (Ellis Horwood, 1990), ISBN 0-13-946880-3, 334 pages, hardcover, sewn-binding, $59.95.

While astronomers had learned a lot about Uranus in the 200-odd years after William Herschel discovered the planet in 1781, it wasn't until the *Voyager 2* flyby in January 1986 that our picture of Uranus became fully rounded. Ellis Miner is a scientist at Caltech's Jet Propulsion Laboratory and a member of the *Voyager* team; his book provides an excellent overview for the interested layreader of this distant world, its moons, and its rings.

Galaxies & Cosmology

Black Holes and the Universe, by Igor Novikov, (Cambridge University Press, 1990), ISBN 0-521-36683-6 (pbk), 176 pages, hardcover, $39.50; paperback, $14.95.

This short and engagingly written book provides a thorough description of what black holes are, how they (probably) function in the universe, and what astronomers know and suspect about them. The intended reader is anyone interested in the subject. (In a nice touch, both editions have sewn bindings.)

Reference Works

Space People — from A-Z, by Ray Spangenburg and Diane Moser, (Facts on File, 1990), ISBN 0-8160-1851-0, 100 pages, hardcover, acid-free paper, $22.95.

This is a biographical dictionary of astronauts, cosmonauts, and space officials and engineers. Most of the entries are single paragraphs, and many have informal photos.

The Cambridge Encyclopedia of Space, edited by Michael Rycroft, (Cambridge University Press, 1990), ISBN 0-521-36426-4, 386 pages, hardcover, sewn binding, $79.50.

This oversized tome is physically a companion to the similar encyclopedia on astronomy published by Cambridge (2nd edition, 1988). It is a collection of short essays on particular topics by some 80 contributors; it uses over 1,000 diagrams and photographs (black & white and color) and a well-written, popular-level text to explain many aspects of space technology. (The book even includes sections on fictional and movie spacecraft designs.) The index, which also functions as a short glossary, is detailed and helpful.

QUICK PICKS

Observing

The Deep Space Field Plan, by John C. Vickers, (Sky Publishing, 1989), ISBN 0-933346-59-X, 267 pages, paperback, $24.95.

Galaxies

Atlas and Catalogue of Infrared Sources in the Magellanic Clouds, by P. B. W. Schwering and F. P. Israel, (Kluwer Academic Publishers, 1990), ISBN 0-7923-0654-6, 213 pages, hardcover, acid-free paper, sewn binding, $99.00.

Astronautics and Space

Space in the 21st Century, by Richard S. Lewis, (Columbia University Press, 1990), ISBN 0-231-06304-0, 234 pages, hardcover, acid-free paper, sewn binding, $29.95.

General

The Search for Life's Origins, by the Space Studies Board of the U. S. National Research Council (National Academy Press, 1990), ISBN 0-309-04246-1, 148 pages, paperback, $16.00.

The Teaching of Astronomy, edited by Jay Pasachoff and John R. Percy, (Cambridge University Press, 1990), ISBN 0-521-35331-9, 445 pages, hardcover, sewn binding, $54.50. □

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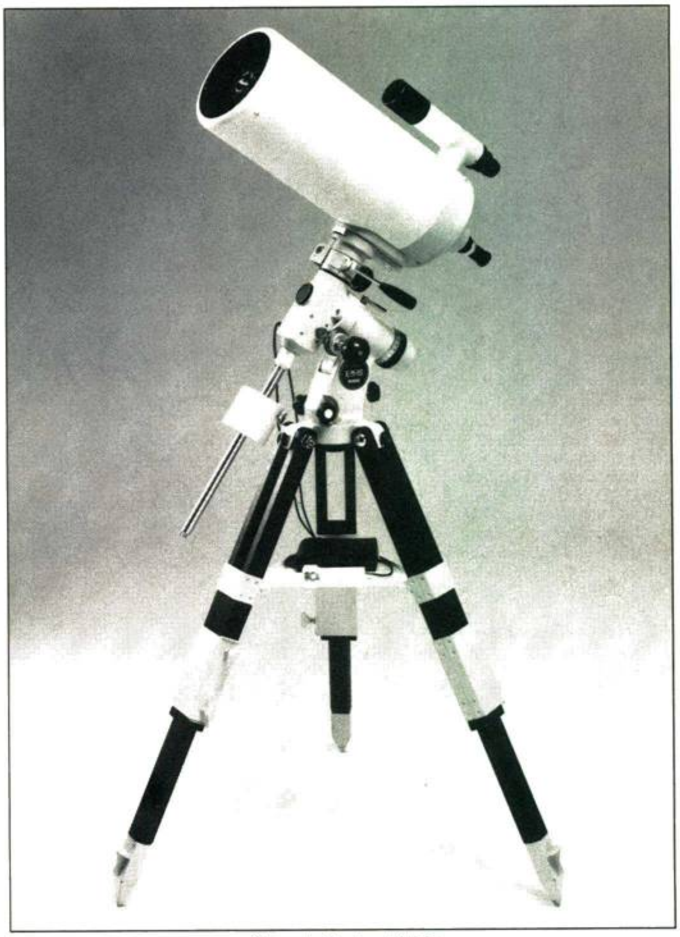

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Meetings & Events

March 14-16
4th Annual Chiefland Star Party, Chiefland, Florida. Sponsored by the Tampa Area Astronomical Society. Contact: John Novak, 9890 82nd Street North, Largo, FL 34647. Phone: (813) 392-4669.

March 30
Astrophoto IX, Thousand Oaks, California. Sponsored by the Ventura County Astronomical Society. Contact: VCAS/Astrophoto IX, P. O. Box 982, Simi Valley, CA 93062.

April 12-14
3rd International Dark-Sky Association Meeting, Hotel Park, Tucson, Arizona. Contact: IDA, 3545 North Stewart Avenue, Tucson, AZ 85716.

April 13
45th Annual Astronomical League North Central Regional Convention, De Pere, Wisconsin. Sponsored by the Neville Public Museum Astronomical Society. Contact: Ronald Parmentier, 161 Rosemont Drive, Green Bay, WI 54301.

April 19-21
Adult Astronomy Camp, University of Arizona, Tucson, Arizona. Sponsored by The University of Arizona's Alumni Association and Steward Observatory. Contact: Joan L. Morrill, Arizona Alumni Association, 1111 North Cherry, Tucson, AZ 85721. Phone: (800) 232-8278 (outside Arizona), or (602) 621-5233.

April 20
Astronomy Day, Contact: Gary Tomlinson, Astronomy Day Coordinator, c/o Chaffee Planetarium, 54 Jefferson SE, Grand Rapids, MI 49503. Phone: (616) 456-3987.

April 20
Astronomy Day 1991, National Air and Space Museum, Washington, D.C. Contact: Cheryl Bauer, Room 3356B, National Air and Space Museum, 6th & Independence Avenue, S.W., Washington, DC 20560. Phone: (202) 357-1529.

April 20
Astronomy Day and 60th Anniversary Celebration, Madison, Wisconsin. Sponsored by the Madison Astronomical Society. Contact: Bob Manske, 404 Prospect Street, Waunakee, WI 53597, (608) 849-5287; or Dave Weier, 205 Cameo Lane, Madison, WI 53714, (608) 241-1444.

April 23-26
28th Space Congress, Cocoa Beach, Florida. Sponsored by the Canaveral Council of Technical Societies. Contact: Canaveral Council of Technical Societies, P.O. Box 321333, Cocoa Beach, FL 32932.

May 10-11
AstroFestival '91, Roberson-Kopernik Observatory, Vestal Center, New York. Sponsored by the Kopernik Astronomical Society. Contact: Roberson-Kopernik Observatory, Underwood Road, Vestal Center, NY 13850. Phone: (607) 772-0660.

May 12-19
Texas Star Party, Fort Davis, Texas. Contact: TSP registrar Bobby Braley, Dept. A, P. O. Box 386, Wylie, TX 75098.

May 17-19
General Assembly of the Royal Astronomical Society of Canada, Vancouver, British Columbia. Contact: David Dodge, Vancouver Centre of the RASC, Gordon Southam Observatory, 1100 Chestnut Street, Vancouver, BC, Canada V6J 3J9.

May 18
Astroganza '91, Abrams Planetarium, East Lansing, Michigan. Sponsored by the Capital Area Astronomy Club. Contact: Kurt Melvin, Abrams Planetarium, Michigan State University, East Lansing, MI 48824. Phone: (517) 546-7089 (evenings).

May 22-27
10th Annual International Space Development Conference, San Antonio, Texas. Sponsored by the National Space Society, Kelly Air Force Base, and the San Antonio Space Society. Contact: Carol Luckhardt Redfield. Phone: (512) 522-3823.

May 24-27
23rd Annual Riverside Telescope Makers Conference, Camp Oakes, Big Bear, California. Contact: RTMC, c/o Fox and Stephens CPA, 9045 Haven Avenue #109, Rancho Cucamonga, CA 91730. Phone: (714) 948-2205. ☐

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Readings and Resources

Alpha Centauri *(page 28)*

Habitable Planets for Man, by Stephen Dole, (American Elsevier, 1970). The classic work that explores what the bounds of liveability are for humans and suggests observational tests for locating potentially habitable worlds.

Intelligent Life in the Universe, by Carl Sagan and I. S. Shklovskii, (Holden-Day, 1966). Although a quarter-century old, this is still one of best and most readable books on the subject of how likely it is that other "Earths" exist elsewhere.

Rendezvous with Venus *(page 38)*

"Venus: The Hellish Place Next Door" by R. Stephen Saunders, ASTRONOMY, March 1990. A good review of current theories about Venus, written by the project scientist with the Magellan mission.

How to Photograph the Eclipse *(page 68)*

"Journey Into Darkness" by Alan Dyer, ASTRONOMY, July 1990. About the eclipse, where it will be visible, and how to get there.

The Galaxies of Sextans *(page 82)*

Deep Sky Observing with Small Telescopes, by David J. Eicher and the editors of *Deep Sky,* (Enslow, 1989). An manual that includes data and amateur telescope observations for galaxies in Sextans.

The Universe from Your Backyard, by David J. Eicher, (Cambridge University Press, 1988). A compilation of ASTRONOMY articles from the years 1983-1987 that includes a four-page section on Sextans with a map, photographs, and observational data to assist backyard astronomers.

CREDITS

Cover: Kitt Peak National Observatory; *p. 4:* NASA/JPL; *p. 22:* S. B. Anderson, Caltech; *pp. 28-29:* painting by Michael Carroll; *p. 30:* art by Steven Davis; *pages 34-35:* art by Steven Davis; *pp. 38-40:* All photos courtesy NASA and the Jet Propulsion Laboratory; *pp. 44-46:* California Association for Research in Astronomy; Keck Foundation; *p. 48:* illustration by Michael Carroll; *pp. 51-52:* Palomar Mountain Observatory; *p. 56:* George R. Viscome, 3-inch f/6.6 refractor, Fuji 100 film, 30-second exposure, taken April 2, 1988; *p. 68:* Richard Berry; *p. 69:* Jacques Guertin, June 1983, Java, Quantum 6 Maksutov telescope, f/19, 1/2-second, Ektachrome 64; *p. 70, top:* Reginald Poole, July 21, 1990, 200mm telephoto; *p. 70, bottom:* Jim Manning, November 1984, 28mm wide-angle lens, 1/30-second, Ektachrome 400; *p. 71:* Alan Dyer, February 1979, Manitoba, Questar 3.5 Maksutov telescope, f/16, Kodachrome 64 film; *p. 72, top:* William Sterne, February 1979, 1/400-second exposures for partial phases, 3-second exposure for total phase, 2 1/4 by 3 1/4 Vericolor II film; *bottom:* Jim Rouse, February 1979, Celestron 5 telescope,1/125-second exposures for all three images, Kodachrome 64 film; *p. 76, top:* Clyde E. Kirkpatrick, 10-inch f/10 SCT at 238x on October 22, 1990; *bottom:* Gregory Terrance, 16-inch reflector at f/135, Tech Pan film, 1-second exposure on November 18, 1990; *p. 77, top:* Edwin Faughn, painting based on eyepiece sketches made with a 4-inch f/15 refractor at 160x and 240x on November 23, 1990; *bottom left:* Gregory Terrance, 16-inch reflector at f/135, Tech Pan film, 1-second exposure on November 21, 1990; *bottom right:* Russ Sampson, 24-inch f/15 refractor (stopped-down to 16-inches aperture) at 310x on October 4, 1990; *p. 78, top:* Gregory Terrance, 16-inch reflector at f/135, Tech Pan film, 1-second exposure on October 27, 1990; *bottom:* Gregory Terrance, 16-inch reflector at f/135, 1-second exposure on November 18, 1990; *p. 79:* Paul Roques, 10-inch SCT, 30-minute exposures, taken June 8 and 10, 1983; *p. 80:* Chris Becker and Alan Dyer; *p. 81:* Alan Dyer; *p.83:* Larry Landolfi; *p. 84, top left:* Michael Stecker; *left center:* C. Dunmill, 50mm f/2.8 lens, Fujichrome ISO 400 film, 10-minute exposure; *bottom left:* Brian Fell, 50mm f/2.8 lens, Ektar 1000 film, 1-minute exposure; *right:* Kim Zussman, 14.5-inch f/8 SCT, hypered Tech Pan film, 110-minute exposure; *p. 85:* Bob King; *p. 86:* Tony Hallas and Daphne Mount, 7-inch EDF refractor, hypered Fuji Super HG film; *p. 87, bottom left:* Bill Hood, 400mm f/8 lens, hypered Fujichrome 400 film, 20-minute exposure; *top right:* Chuck Vaughn, 500mm f/4 lens, hypered Tech Pan film, Ha filter, 110-minute exposure; *bottom right:* Kim Zussman, 14.5-inch f/8 SCT, hypered Tech Pan film, 115-minute exposure; *p. 85:* Jeffrey L. Jones, 8-inch f/10 SCT, hypered Tech Pan film, 120-minute exposure; *p. 86:* Preston S. Justis, 10-inch f/6 reflector, 103a-F film, 45-minute exposure; *p. 87:* Lee C. Coombs, 10-inch f/5 reflector, 103a-0 film, 15-minute exposure.

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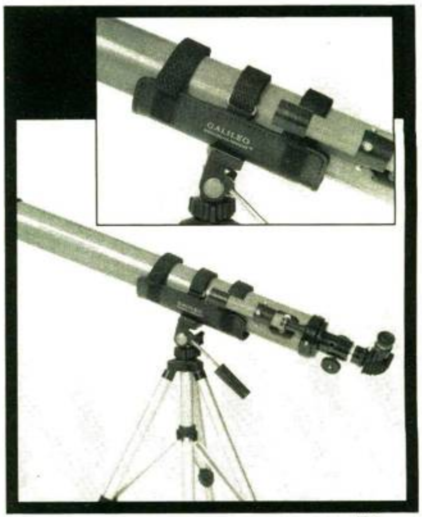

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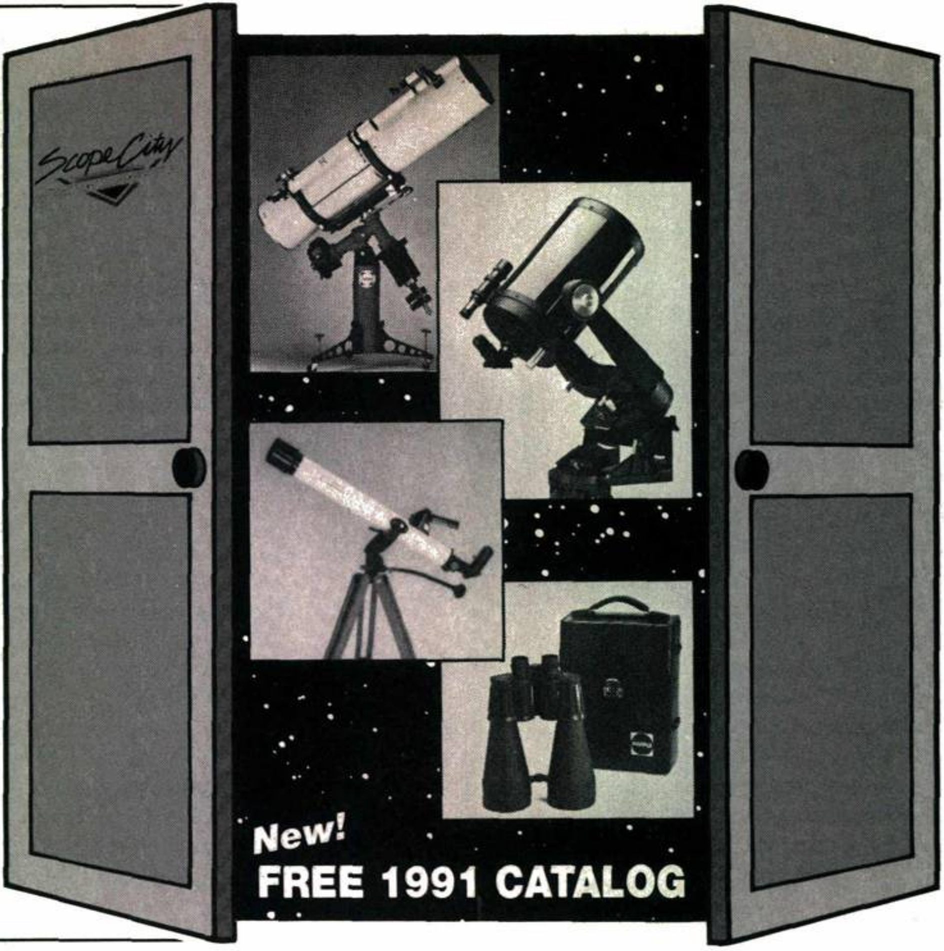

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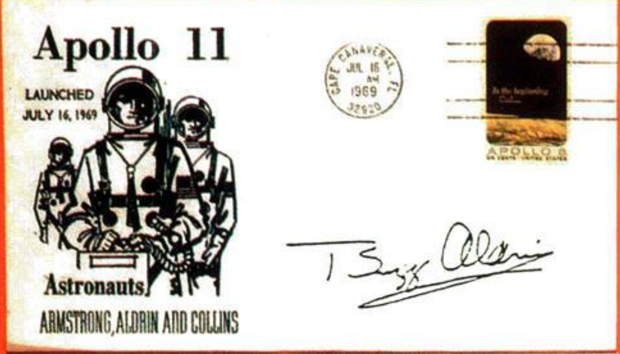

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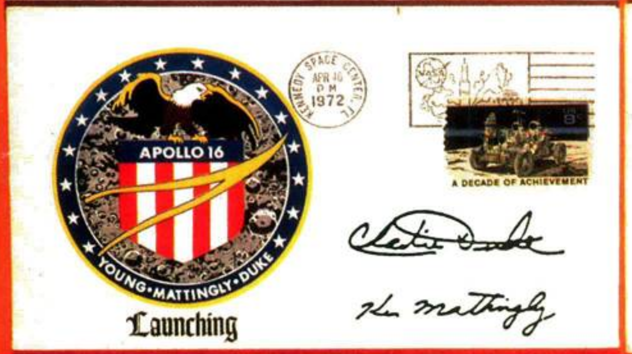

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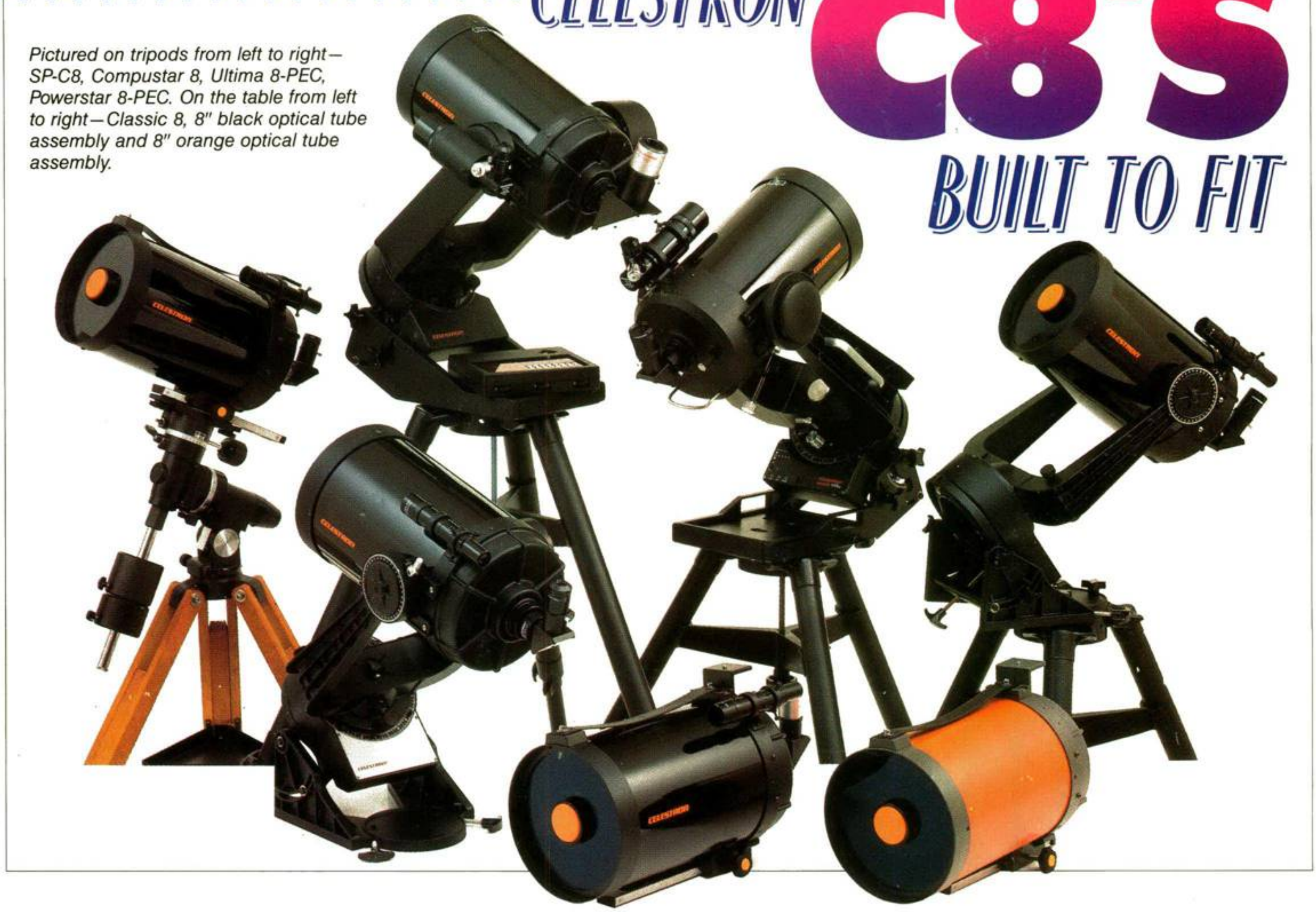

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